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The Magnetron and the Generation of Ultra-short Waves

THE great amount of attention which is being devoted to the magnetron is mainly due to the fact that it is capable of generating with a reasonable efficiency oscillations at frequencies beyond those at which it is possible to operate the ordinary thermionic valve generator. The action of the magnetron is, however, very diverse and complicated, and a general review of the subject, with special reference to the generation of ultra-short waves, has recently been published by the Research Laboratories of the German Post Office.* The magnetron, as usually constructed, has a radial electric field between the axial cathode and the cylindrical anode, giving the electrons a radial acceleration; it has also a magnetic field parallel to the filament, and therefore normal to the electric field. This causes the moving electrons to follow curved paths. Superimposed on these steady fields there may be alternating electric or magnetic fields which, although small compared with the steady fields, play an important rôle in the operation of the magnetron. The original magnetron of Hull acted as an amplifier, the input varying the magnetising current, which was adjusted to the critical value for the anode voltage employed. For each value of anode voltage there is a value of the magnetic field for which the anode current is very sensitive to small changes in the magnetic field. With weaker fields nearly all the electrons reach the anode; with stronger fields their path is so curved that they return to the cathode. Instead of varying the magnetic field it is usually more convenient to vary the anode voltage, and in nearly all the recent developments the magnetic field is maintained constant. Originally, the magnetron generator had the oscillatory circuit connected between the anode and cathode, but a great step in advance was made by slitting the anode along its length on both sides of a diameter, thus making it into two half cylinders, between which the oscillatory circuit is connected. In some cases this is carried farther, and the cylinder is split into three, four, six or more sectors. Such split anodes can be connected to single-phase or three-phase oscillatory circuits as shown in Fig. 1 (a) and (b). In both cases the number of slits $s=6$. If one imagines a rotating arm connecting the cathode to the anode segments it is seen that a complete revolution in (a) corresponds to three cycles and in (b) to two cycles, so that we may say that in (a) the number of pole pairs $p=3$, whereas in (b) $p=2$.

Such a slit anode magnetron has a static characteristic which is falling over a certain range corresponding to a negative A.C. resistance. Its action as a generator can be calculated from the slope of the characteristic, but the results do not agree with experiment for waves below a certain length. As the wavelength is progressively decreased, the want of agreement becomes more pronounced, the efficiency is much greater than the calculated, and the operative part of the characteristic is no longer that with a negative slope. For the longer waves, at which the so-called dynatron oscillations occur, the magnetron is inferior to the ordinary valve oscillator. It is only when, owing to the very high frequency, the transit time of the elec-

* Otto Groos, *E.N.T.*, p. 325, October, 1937.

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trons from the cathode to the anode is no longer negligible compared with the period of oscillation, and the action is no longer explicable from the static characteristic, that the magnetron comes into its own, and not only generates oscillations which are beyond the frequency range of the ordinary valve,

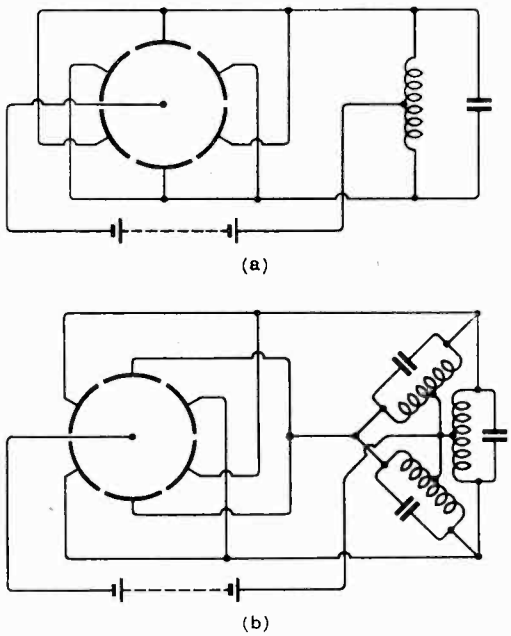

Fig. 1.—(*a*) *Single-phase*, $s = 6$, $p = 3$; (*b*) *Three-phase*, $s = 6$, $p = 2$.

but does so at a reasonable efficiency. When oscillating, the circuit voltage is superimposed upon the steady anode voltage and the radial electric field is pulsating. The electrons follow curved paths which involve a to-and-fro radial movement. Whether they absorb energy or deliver energy depends on the relative phase of their radial movement and the alternating component of the radial electric field. If their to-and-fro radial movement is of the same frequency as the oscillations in the external circuit, the oscillations are said to be of the first order ($n = 1$). Such oscillations can occur with plain or with slit anodes; the efficiency is usually less than 10 per cent., and, although the frequency is little affected by changes in the external circuit, an efficiency of even 10 per cent. can only be obtained by carefully tuning the external circuit to the electron frequency. A peculiarity of this type of operation is that the magnetron will only act as a generator if some means are introduced to remove the electrons after they have been a certain time in the inter-electrode space. One method of attaining this is to apply a voltage between two plates placed at the ends of the cylinder, thus giving the electrons an axial acceleration due to the electric field. A more commonly applied method is to arrange the magnetic field so that it is not axial but at a small angle (5 to 10 degrees) to the axis of the cylinder and cathode. The output and efficiency are very sensitive to the correct adjustment of the end-plate voltage or of the angle of the magnetic field. By using an anode of very small radius a very high anode voltage and a consequently very strong critical magnetic field, a wavelength of 1 cm. has been obtained, but the low efficiency of this type of oscillation is a serious disadvantage.

Oscillations of a higher order, that is, those for which the to-and-fro or spiral frequency of the electrons is a multiple of the working frequency—can be generated in slit-anode magnetrons. They differ from those just considered in that they have a higher efficiency, a larger relative value of the alternating component of the anode voltage, and a frequency which is largely controlled by that of the oscillatory circuit. They also differ in that the highest efficiency is obtained when the magnetic field is exactly axial and not inclined at an angle, which indicates some fundamental difference between the mechanism of the two types of oscillation. The P.D. between the sections of the anode produces an alternating tangential electric field which may be regarded as made up of two rotating tangential fields, one of which is rotating in the same direction around the cathode as the electrons, which can thus give up energy which they absorbed in their radial movement.

For very short waves one is compelled to use the unslit anode in spite of its inefficiency. The dimensions are necessarily very small and water cooling is essential if a considerable output is to be obtained. Rice* has described such a magnetron in which the copper wall of the tube acted as the anode. The ends of the tube were of glass and carried the cathode connections, these glass ends being water-cooled. To obtain a wavelength λ of 4.8 cm. the anode voltage was 3,050, the magnetic field strength 3,300, the

* Rice, *Gen. Elec. Rev.*, 39, p. 363 (1936).

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output 3 watts, and the efficiency only about 1 per cent. If the wavelength is increased to 25 or 50 cms. efficiencies of 30 to 50 per cent. can be obtained by using anodes with 2 or 4 slits, and the output increased to several hundred watts, but the constructional difficulties are increased. A number of constructional diagrams are given in the report by Groos.

A difficulty which is merely mentioned by Groos, but discussed more fully by Helbig† is that with high anode voltages the electrons which return to the cathode strike it with such a high velocity that the cathode is heated thereby. This may cause such an increase in the anode current that the valve will be destroyed unless means are adopted to prevent it. An obvious precaution is to insert resistance in the anode circuit, but this reduces the overall efficiency of the generator. Helbig describes experiments with a novel type of magnetron designed to prevent the return of the electrons to the cathode. Instead of using a heated filament forming the axis of the cylindrical anode, he coils the filament into a flat spiral and places it just outside the cylinder as shown in Figs.

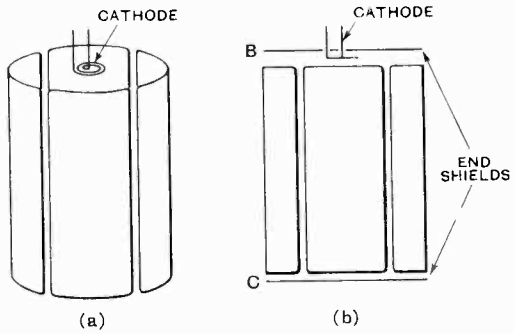

Fig. 2.—*Helbig's magnetron.*

2 (a) and (b). The electrons will now have a component velocity parallel to the axis of the cylinder and will follow a spiral path before reaching the anode. To prevent them emerging at the ends and striking the glass enclosure flat plates are arranged as shown and connected to the cathode. The electrons do not return to the filament, which is, therefore, not subjected to their bombardment, but the filament is now subjected to mechanical forces due to it carrying current in the magnetic field. Helbig finds that the emission can be controlled by varying the potential of the baffle plate B (Fig. 2b), and suggests that this provides a ready means of modulating the output. It does not appear to have been tried, however, and one cannot say to what extent this method would be free from the fault of other methods which modulate both amplitude and frequency.

† Helbig, *Hochf:tech. u. Elek:akus*, Sept. 1937, p. 96.

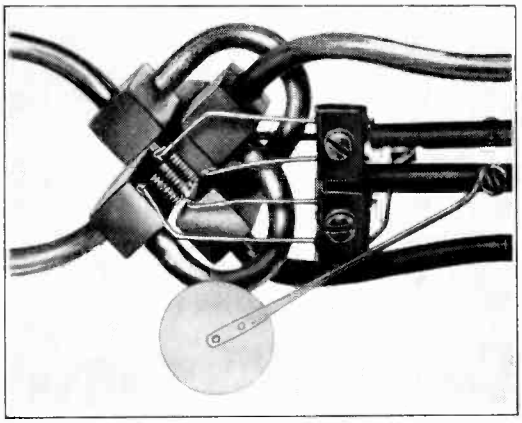

Fig. 3.—*Details of Helbig's magnetron.*

Fig. 3 shows the arrangement of Helbig's magnetron. The four anode sectors consist of water-cooled copper boxes, cross-connected by copper tubes. The right-hand tubes are the anode supply leads and those on the left go to the Lecher system which serves as the oscillatory circuit. The cathode can be seen at the rear end of the space between the segments, and the adjustable disc B (Fig. 2b) is in the foreground. With this magnetron Helbig claims to have obtained an output of 200 watts at a wavelength of 90 cm. with an efficiency of over 30 per cent. Although Helbig does not mention it, there appears to be no reason why there should not be a similar spiral cathode at both ends of the cylinder, thus removing the want of symmetry. Helbig states that these experiments were made two years ago, but that, being unable to follow them up, he has published the results in the hope that others may be able to do so.

The magnetron offers a large field both for theoretical and experimental research.

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Super-Regeneration with Reference to Broadcast Receivers *

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PART I.—THEORY

A. General theory of circuit containing inductance, capacitance and variable resistance. Amplification due to super-regeneration.

B. Multiple resonance due to super-regeneration.

C. Selectivity of the super-regenerative circuit.

D. Automatic volume control action due to super-regeneration.

E. Quality of reproduction and characteristic hiss due to super-regeneration.

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PART II.—PRACTICE

A. General details.

B. Conclusions.

PART I

A. Amplification Due to Super-Regeneration

IN a general manner, super-regeneration may be said to be a method of obtaining amplification in a valve amplifier by periodic variation of the resistance of a tuned circuit by a small amount—about a value as near to zero as possible.

There are two ways of regarding the resultant phenomena.

We can consider the amplification obtained as being the result of :

(*a*) The strong local oscillation set up during the time when the circuit resistance was negative or nil.

(*b*) The mean $Q = \frac{L\omega}{r}$ taken over a complete period of resistance variation.

We shall use mainly reason (*b*) as it is distinctly simpler.

The reason the resistance must vary periodically instead of remaining continually negative or nil is that the amplifier would simply become an oscillator whose output would be quite constant and completely independent of the input. When the resistance becomes positive the local oscillation is, and must be, damped out so that when next the resistance becomes zero the new local oscillation set up will start at an amplitude directly proportional to the input.

* MS. accepted by the Editor, April, 1937.

If the frequency of variation of resistance is in the audible range, the output from the amplifier would be modulated at this frequency. This property can be used for the reception of pure C.W. telegraphy.

If the frequency of variation is above the audible range, reception of modulated C.W. is quite feasible.

Consider an LCr circuit with an A.C. series generator in it. This circuit will represent the grid circuit of the super-regenerator valve and the series generator will generate a voltage E across r, E being due to the aerial or H.F. amplifier coupling coil.

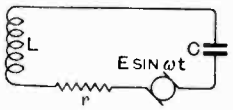

Fig. 1.

The frequency, ω, of E, will be taken equal to the resonant frequency of L and C, so that the series e.m.f. in the circuit will be E. Now let r be a sinusoidal function of time with a period equal to the quenching period, that is, let

$$r = R_m \sin pt \quad \ldots \quad \ldots \quad (1)$$

where $p = 2\pi \times$ quench frequency.

The differential equation of such a circuit is

$$L\frac{di}{dt} + R_m \sin pt \,.\, i + \frac{1}{C}\int i\,dt = E \sin \omega t. \quad \ldots \quad (2)$$

We shall now make a fundamental assumption. Let us assume that, as the period of E is that of the LC circuit by definition, we can treat $E \sin \omega t$ as a constant steady state voltage of value E.

Then differentiating once more :

$$L\frac{d^2i}{dt^2} + R_m \sin pt\frac{di}{dt} + \left(\frac{1}{C} + pR_m \cos pt\right) i = 0 \quad \ldots \quad \ldots \quad (3)$$

as, E being considered a constant

$$\frac{dE}{dt} = 0$$

The solution of this equation is extremely difficult, but has been done by H. Ataka (*Proc. I.R.E.*, August, 1935).

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If $a = \frac{R_m}{2L}$ and $m = \frac{a}{2\omega}$

the solution can be written :

$$i = Ie^{a/p \cdot \cos pt} \cdot \cos(\omega t + m \sin pt) \quad .. \quad (4)$$

The factor $\cos(\omega t + m \sin pt)$ represents a high frequency current of constant unit amplitude, whose wave shape is sinusoidal except for an abrupt phase change after each quench cycle of frequency $\frac{p}{2\pi}$.

The factor $Ie^{a/p \cdot \cos pt}$ can be considered as the envelope of $\cos(\omega t + m \sin pt)$. It is this envelope which interests us, as it can be used to obtain an approximate formula for the amplification of the super-regenerative circuit.

We shall now assume that at any instant the current and the voltage will be proportional to this envelope.

Theoretically, v should be

$$LI \frac{d}{dt}\left[e^{a/p \cdot \cos pt} \cdot \cos(\omega t + m \sin pt) \right]$$

but the phase change due to the term $m \sin pt$ can be overlooked in an approximate study ; and as the frequency of variation of $e^{a/p \cdot \cos pt}$ is negligible compared with that of $\cos \omega t$, we can use the steady state laws with respect to ω.

Let us write, then

$$v = Ke^{a/p \cdot \cos pt} \quad .. \quad .. \quad (5)$$

where v is the voltage across L at any instant and K is a constant of proportionality equal to

$$K = L\omega I \quad .. \quad .. \quad (6)$$

Now I is the constant of integration from expression (4) which can be determined from boundary conditions. It will be noted that the envelope of i, that is

$$e^{a/p \cdot \cos pt}$$

is $\frac{\pi}{2}$ radians out of phase with the resistance,

$$R_m \sin pt$$

So that for $pt = \frac{\pi}{2}$

we have

$$e^{a/p \cos pt} = 1 \quad .. \quad .. \quad (7)$$

and $$i = I \times 1 \quad .. \quad .. \quad (8)$$

and moreover, $R_m \sin pt = R_m$

And since at any instant

$$E = ir \quad .. \quad .. \quad (9)$$

we have finally

$$E = IR_m$$

So $$I = \frac{E}{R_m} \quad .. \quad .. \quad (10)$$

So v becomes

$$v = \frac{L\omega E}{R_m} e^{a/p \cos pt} \quad .. \quad (11)$$

Now the amplification in the grid circuit, caused by super-regeneration, can be considered as the quotient of the mean value of v over a quench period and E. Let this amplification be written P ; then

$$P = \frac{L\omega}{R_m} \cdot \frac{1}{T} \int_0^T e^{a/p \cdot \cos pt} \, dt \quad .. \quad (12)$$

Now let $pt = \theta$

then $dt = \frac{1}{p} d\theta$

and the amplification becomes

$$P = \frac{L\omega}{R_m} \cdot \frac{1}{2\pi} \int_0^{2\pi} e^{a/p \cdot \cos\theta} \, d\theta \quad .. \quad (13)$$

But $$\frac{1}{2\pi} \int_0^{2\pi} e^{a/p \cdot \cos\theta} \, d\theta = \frac{1}{\pi} \int_0^{\pi} e^{a/p \cdot \cos\theta} \, d\theta = I_0\left(\frac{a}{p}\right)^*$$

So the amplification now becomes

$$P = \frac{L\omega}{R_m} I_0\left(\frac{a}{p}\right) = \frac{L\omega}{R_m} J_0\left(j\frac{a}{p}\right) \quad .. \quad (15)$$

where I_0 is a modified Bessel function of the first kind and zero order.

The function $I_0(z) = J_0(jz)$ where $j = \sqrt{-1}$ has been tabulated and a set of tables may be found in "Tables of Functions," by Jahnke and Emde, p. 278.

The function $I_0(z)$ is shown approximately in Fig. 2.

From this it will be seen that the function increases from Unity to Infinity as z increases from zero to infinity.

Now $$\frac{a}{p} = \frac{R_m}{2Lp}$$

and in order to discover the trend of the amplification, P, in function of L, ω, R_m,

* See N. W. McLachlan, Bessel Functions for Engineers, pp. 105 and 162.

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and p in a qualitative manner, we can assume, very approximately, that, for $\frac{a}{p} < 1$, which is the case for

$$* \begin{cases} R_m = \frac{1}{10} \text{ ohm} \\ L = 1.6 \times 10^{-6} \text{ henries} \\ p = 2\pi \times 20{,}000 \text{ c/s.} \end{cases}$$

$I_0\left(\frac{a}{p}\right)$ is nearly linear and nearly equal to

$$I_0\left(\frac{a}{p}\right) \approx 1 + A\frac{a}{p} \quad .. \quad .. \quad (16)$$

A being a numerical constant.

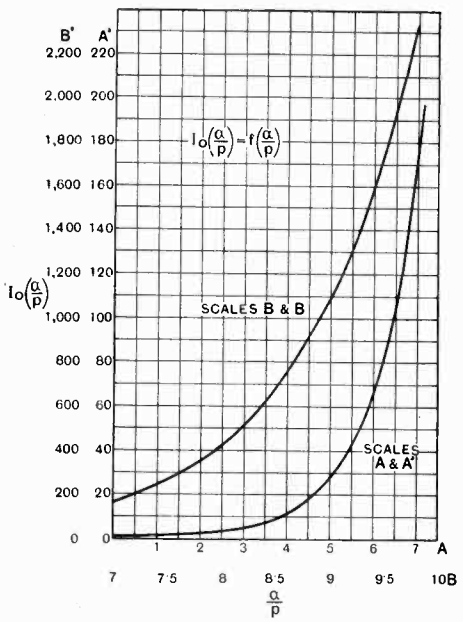

Fig. 2.

Putting expression (16) into expression (15), we get

$$P \approx \frac{L\omega}{R_m}\left(1 + A\frac{R_m}{2Lp}\right) \quad .. \quad .. \quad (17)$$

or $P \approx \frac{L\omega}{R_m} + A_1\frac{\omega}{L_p}$ where $A_1 = \frac{1}{2}A$ .. (18)

We are now in a position to say that for

$$\frac{R_m}{2Lp} < 1$$

* Normal values for a certain short wave broadcast band.

the amplification P increases as L and ω, and increases as R_m and p diminish, which facts are observed in practice.

B. Multiple Resonance due to Super-Regeneration

For the purpose of calculating the amplification, we neglected, in expression (4), the H.F. term

$$\cos(\omega t + m \sin pt)$$

If the term $\cos(\omega t + m \sin pt)$ is included in the final current equation—not the mean current equation—it has been found (H. Ataka, *Proc. I.R.E.*, August, 1935) that the resonance curve of the circuit presents a major resonance at ω, plus resonances of diminishing importance at $\omega \pm Kp$, where K is an integer. It would appear from this that multiple resonance is intrinsically a part of super-regeneration. It has been found in practice, however, that multiple resonance is only encountered when the negative resistance in the circuit becomes high, that is, when the reaction coil is tightly coupled to the grid circuit of the super-regenerator valve. This can be explained in the following manner.

In developing expression (4), Ataka found that the terms of high frequencies $\omega \pm Kp$ had amplitudes approximately equal to

$$J_k(m)\left(1 \pm K\frac{a}{p}\right)$$

Let us, then, take the amplitude of the component of frequency ω and divide it by the amplitude of the component of frequency $\omega + p$, that is, the first "off resonance" peak. We have, then

$$\frac{J_0(m)}{J_1(m)\left(1 + \frac{a}{p}\right)} \quad .. \quad .. \quad (19)$$

Now for multiple resonance to be small we want $J_0(m)$ to be great before

$$J_1(m)\left(1 + \frac{a}{p}\right)$$

This means

$$\frac{J_0(m)}{J_1(m)\left(1 + \frac{a}{p}\right)}$$ to be as large as possible.

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Developing the Bessel functions, we find this ratio to be equal to

$$\frac{1-\frac{m^2}{4}}{m\left(\frac{1}{2}+\frac{\omega m}{2}\right)} \text{ as } m^4 << m^2 \text{ in practice} \quad .. \quad (20)$$

So that, if it is to be large, we want

$$1-\frac{m^2}{4} >> \frac{m}{2}+\frac{\omega}{p}m^2$$

or $$\left(\frac{\omega}{p}+\tfrac{1}{4}\right)m^2+\tfrac{1}{2}m << 1 \quad .. \quad (21)$$

If $\frac{\omega}{p}$ is fixed, this means that m must be small, as it is essentially a positive quantity, being equal to

$$m=\frac{R_m}{4L\omega}$$

If L is also fixed, it means that R_m must be small. Now if the reaction in the super-regenerator valve be increased, it will be necessary to increase the quench voltage in order adequately to quench out the generated local oscillation, which means that R_m will be increased, which will decrease the ratio in expression (20) as m will increase.

Another way of making m large is when the $\frac{L}{C}$ ratio of the super-regenerator circuit, that is the LCr circuit of Fig. 1, becomes small; that is to say, when tuning to the top of the waveband for which L and C were designed. During this operation L remains constant, while ω is diminishing and therefore m increases. Again, this operation should therefore produce multiple resonance and in practice it does. As many as twenty-two resonances were noted with comparative ease near to the frequency corresponding to the minimum $\frac{L}{C}$ ratio.

C. Selectivity of the Super-Regenerative Circuit

The selectivity of a single parallel-tuned circuit LCr may be defined as the ratio of circulating current at resonance to circulating current at $d\omega$ off resonance. Call this ratio S. The band-width is obviously

$$2\frac{d\omega}{2\pi}=\frac{d\omega}{\pi}$$

Now S is evidently equal to the ratio

$$S=\frac{Z(\omega_0 \pm d\omega)}{r} \quad .. \quad (22)$$

where $Z(\omega_0 \pm d\omega)$ is the series impedance of the circuit at angular frequency $\omega_0 \pm d\omega$. Then

$$S=\sqrt{1+\frac{\left(L\omega-\frac{1}{C\omega}\right)^2}{r^2}} \quad .. \quad (23)$$

which can be written

$$S=\sqrt{1+\left(\frac{2L}{r}\right)^2(d\omega)^2\,\tfrac{1}{4}\left(1+\frac{\omega_0}{\omega}\right)^2} \quad .. \quad (24)$$

In practice, at wavelengths between 15 and 100 metres the half band width with super-regeneration is such that the term

$$\tfrac{1}{4}\left(1+\frac{\omega_0}{\omega}\right)^2$$

can be taken equal to unity, so that S may be written

$$S=\sqrt{1+\left(\frac{2L}{r}\right)^2(d\omega)^2} \quad .. \quad (25)$$

Remembering that the band width is

$$\text{B.W.}=\frac{d\omega}{\pi}$$

we get from expression (25)

$$\text{B.W.}=\frac{\sqrt{S^2-1}}{\pi\frac{2L}{r}} \quad .. \quad .. \quad (26)$$

We shall now extend this definition of selectivity of a plain parallel-tuned circuit to that of the super-regenerative circuit of Fig. 1. Mathematically, this is an extremely risky procedure, but the object of this study being to obtain formulae which will be useful in practical work, we shall not hesitate to make any assumptions which simplify the problem without putting the results too far in error.

The amplification of a simple parallel-tuned circuit, at resonance, is the ratio of the parallel voltage to the series voltage, that is

$$\frac{\text{v. parallel}}{\text{v. series}}=\frac{L\omega}{r}=Q \quad .. \quad (27)$$

Working on this basis, we found the amplification due to super-regeneration to be expression (15).

$$P=\frac{L\omega}{R_m}I_0\left(\frac{a}{p}\right)$$

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Let us then define a super-regenerative Q by equating Q to P.

$$P = \frac{L\omega}{R_m} I_0\left(\frac{a}{p}\right) = \frac{L\omega}{r} = Q \quad .. \quad (28)$$

$$\text{So that} \qquad r = \frac{R_m}{I_0\left(\frac{a}{p}\right)} \quad .. \quad .. \quad (29)$$

Expression (26) now becomes

$$\text{(B.W.) super-regenerative} = \frac{R_m\sqrt{S^2 - 1}}{2\pi L\, I_0\left(\frac{a}{p}\right)} \quad .. \quad (30)$$

D. Automatic Volume Control Action due to Super-Regeneration

It is often stated that super-regeneration is accompanied by an A.V.C. action. We found this to be true to a marked extent. The action is due to the fact that the grid circuit, which is periodically put into oscillation by the removal of the positive resistance during the appropriate half of the quench cycle, may saturate with a sufficiently strong signal before the positive resistance is re-inserted as it has been assumed that the voltage on the grid circuit though building up according to

$$e^{a/p} \cdot \cos pt$$

still remains proportional to the incoming signal E. It may be possible to formulate an expression for the magnitude of E at the threshold in function of the circuit and valve constants, but we have failed to find one of sufficient accuracy to be of use.

E. Quality of Reproduction and Characteristic Hiss due to Super-Regeneration

We see no reason why distortion should be any greater with a super-regenerative detector than with an ordinary leaky grid detector, provided that the receiver is operated with an input signal e.m.f. less than the A.V.C. threshold e.m.f. Rather should the distortion due to grid characteristic curvature be less as the operating grid voltage is usually higher than with normal leaky grid detection.

The characteristic frying hiss has been adequately explained by H. Ataka (*Proc. I.R.E.*, August, 1935) who found that it was due to the highly sensitive super-regenerative circuit being put into oscillation at the time when $r = R_m \sin pt = 0$ by electronic valve discontinuities in the absence of signal. Effectively, when the receiver is put into a reasonably but not too highly sensitive state, the presence of a signal eliminates (not merely masks) the hiss. If the maximum amplification possible is desired, the hiss must be put up with.

F. Stability of the Super-Regenerative Circuit

The question of stability is of first importance as it is this that limits the amplification and selectivity obtainable. P. David in the *Onde Electrique*, 1925 and 1928, stresses the fact that the local oscillation built up during the negative resistance cycle must be adequately damped out during the subsequent positive resistance period. If this is not arranged, in practice, the super-regenerator will act like a more or less ordinary reaction detector wherein the reaction has been increased until the detector is oscillating. The problem is to find out how near to the stability limit one may work and what determines the stability limit. The problem can be solved in an approximate but easy manner by assuming that during the positive resistance cycle the super-regenerative circuit has a *constant* resistance

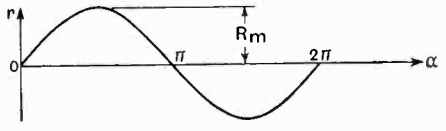

Fig. 3.

equal to the mean value of the real sinusoidal resistance. This mean value is, of course (see Fig. 3)

$$\frac{1}{\pi}\int_0^{\pi} \sin a\, da = \frac{2R_m}{\pi}$$

or in absolute value just $\frac{2}{\pi} R_m$.

The mean time constant of the circuit in question during the positive resistance cycle will be, then

$$\theta = \frac{2L}{\frac{2}{\pi}R_m} = \frac{\pi L}{R_m}$$

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It will be noted that this time constant depends only on the inductance and the amplitude of the resistance of the circuit, and not at all on the quench frequency. Now θ is the time taken for the oscillation existing at the end of the negative resistance cycle to become damped to $\frac{1}{e} = \frac{1}{2.7}$ of its initial value. To judge the limit of stability we must compare θ with one-half of the quench period. If this half quench period is equal to a time much greater than θ, then clearly the circuit will be stable, as there will be ample time adequately to damp out the local oscillation. If, on the other hand, θ and $\frac{1}{2} \cdot \frac{2\pi}{p} = \frac{\pi}{p}$ are comparable values, the circuit will be close to, or beyond the stability limit. We can now say that the greater the quantity

$$\frac{\pi}{p} - \theta \quad \text{or} \quad \left(\frac{1}{p} - \frac{L}{R_m}\right)\pi \qquad .. \quad (31)$$

the more stable the circuit; or conversely, the smaller that quantity, the higher the amplification and the greater the selectivity—up to the limit of stability.

Since radiotelephony and broadcasting were in mind, the quench frequency chosen had to be well above the audio frequency band. The figure of 25 kilocycles per second was chosen. This rather high value brought the limit of stability uncomfortably close (expression (31)) on several occasions.

In order to preserve the maximum of simplicity, a 3-valve circuit was employed, using a H.F. pentode amplifying valve, a triode hexode super-regenerative detector, a quench frequency filter, and a L.F. output pentode. A couple of circuits using a triode as super-regenerative detector are included for general interest. The advantage of the triode hexode over a simple triode, for experimental purposes, was that in the former all variables could be separately and individually controlled and measured.

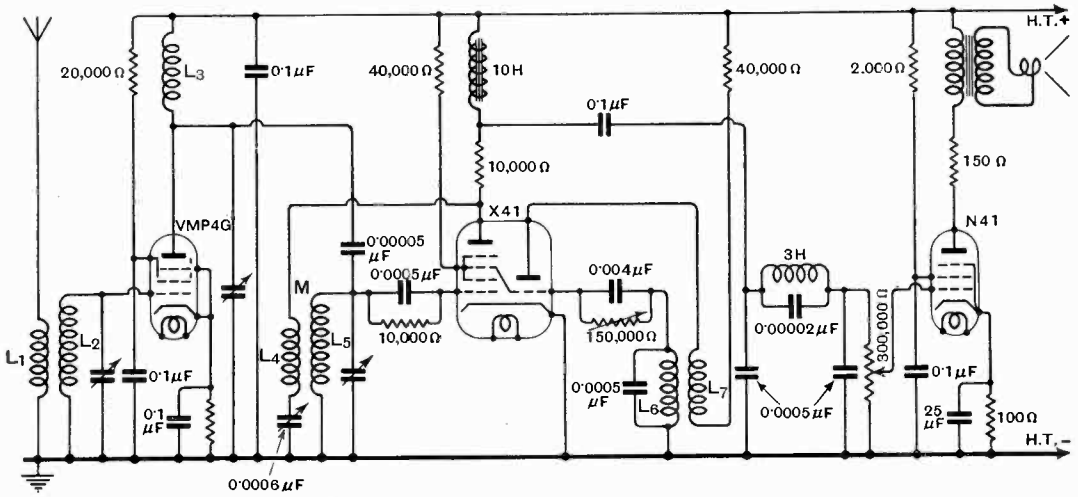

Fig. 4.—$L_1 = 3\ \mu H$; L_2, L_3 *and* $L_5 = 1.6\ \mu H$; $L_4 = 1.4\ \mu H$; $L_6 = 80\ mH$; $L_7 = 40\ mH$; $M = 0.5\ \mu H$ *approx.*

Fig. 4 includes the circuit diagram of the receiver. The quench frequency filter, whose circuit is included in Fig. 4, was intended as an impedance to voltages of quench frequency which would otherwise saturate the output pentode. Its attenuation curve is given in Fig. 5.

Most of the experimental work was done on the 15–50 metre band, this being on the limit of the high frequencies whereat super-regeneration was known to be of use, and also on the limit of the lower frequencies whereat it was considered to be of little use.

In order to correlate, as well as possible, figures of amplification and selection with

PART II

A. General Details

Several simple broadcast receiver circuits were constructed in order to put the foregoing considerations to a test.

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values of actual negative and positive resistance inserted into the super-regenerator grid circuit, the circuit in Fig. 8 was made up. This circuit enabled the figures in Table I to be measured and calculated.

Let us consider Table I. Columns 2, 3, 4 and 5 were measured with a signal generator. Column 6 equals column 3 plus column 5 divided by 2. Column 8 was measured with a valve voltmeter. Column 9 represents grid bias battery volts. Column 7 was calculated from expressions (30) and (28) of the theory after the following simplification was observed.

In Figs. 4 or 8 it will be noted that there are 3 H.F. tuned circuits, the third one being the super-regenerative circuit. Now the Q of the first two circuits is about 187 (measured on a Q-meter). The Q of 2 identical circuits, weakly coupled, can be shown to be $\sqrt{2} \cdot Q$, where Q is the factor $\frac{L\omega}{R}$ of either of the circuits (R. Mesny, *Radioélectricité Générale*). The band width resulting from these two circuits at 14.3 megacycles per second amounts to 0.546 Mc/s

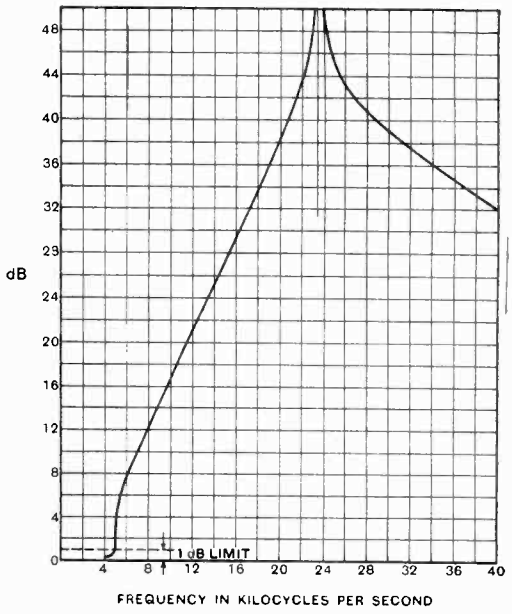

Fig. 5.—*Attenuation curve for Filter B correctly terminated.*

TABLE I.

R_m	Sensitivity in μV. for $\frac{1}{2}$ v. across Speech Coil.	$f - df$. Mc/s.	f. Mc/s.	$f + df$. Mc/s.	Mean $\frac{1}{2}$ Band Width for 10 times down. Mc/s.	P (super regen. Q.)	X.41 Osc. Grid Amplitude. Volts.	X.41 Osc. Grid Bias. Volts.	Remarks.
0.234	20	14.19	14.32	14.41	0.110	653	2.13	−1.5	No hiss. Rather unstable.
0.210	20	14.19	14.31	14.39	0.100	716	1.78	−1.5	No hiss, more stable, more reaction, tendency to squeg with too much reaction.
0.187	20	14.19	14.29	14.37	0.090	793	1.515	−1.5	No hiss, more reaction, tendency to squeg.
0.344	14	14.115	14.275	14.42	0.153	466	3.68	−3.0	No hiss, more reaction, much more stable.
0.277	14	14.115	14.24	14.37	0.128	556	3.11	−3.0	No hiss, more reaction, still stable.
0.258	12	14.09	14.21	14.33	0.120	593	2.66	−3.0	No hiss, more reaction, still stable.
1	2	3	4	5	6	7	8	9	10

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(expression (26) of theory). In other words, compared with the super-regenerative selection, that offered by these two circuits is negligible (see Col. 6, Table I). Column 1 was calculated from expression (28) of the theory by approximations. Values of R_m were tried until the expression

$$R_m = \frac{L\omega}{p} I_0\left(\frac{a}{p}\right)$$

was found to be satisfied.

L was taken equal to 1.6 μH.

$\frac{a}{p}$ was taken equal to $\frac{R_m}{2Lp}$

with $p = 2\pi \times 25{,}000$.

p and ω were taken from columns 7 and 4 respectively.

If columns 9, 8 and 1 are closely studied it will be noted that for constant oscillator-mixer-grid bias the inserted resistance R_m diminishes as the mixer grid voltage—which is to be expected. More values than those in Table I are unnecessary, as these themselves are already especially chosen " near optimum " values.

It will be seen from column 7 that though the P's (" Q ") are better than with a normal short-wave circuit, they are certainly far less than the Q's obtainable with adjustable reaction. The best band-width obtainable was 2×0.090 Mc/s = 180 kc/s, which is quite inadequate.

Another point is that when the grid bias volts are appropriately adjusted and the quench volts reduced to a minimum consistent with stability, the sensitivity of the reaction control becomes practically as great as with a normal adjustable reaction receiver.

As regards the amplification considered without relation to stability, selectivity or sensitivity of controls, it will be seen from column 2 to be satisfactory. If a certain amount of hiss is not too annoying, the sensitivity can be around 5 to 10 μvolts, but in this condition the signal becomes modulated by the hiss as well as added to it.

From the foregoing remarks it will be evident that for a super-regenerative detector to work over a range of frequencies the reaction must be controlled and also the quenching voltage.

At the low frequency end of the 15 to 50 metre band, multiple resonance becomes very pronounced as explained in Part IB of the theory. Table II is included for general interest.

To put the expression (15) of the theory to a very approximate test the following calculation was performed.

Assume an input voltage of e, let the H.F. pentode have a mutual conductance of 2.5 mA/volt ; then the anode oscillatory current will be

$$e \times 2.5 \times 10^{-3}$$

TABLE II

FREQUENCIES OF MULTIPLE RESONANCE AT ABOUT 50 METRES.

Frequency of Resonance.	*df.**
kc/s.	kc/s.
6,220	20
6,200	24
6,176	21
6,155	28
6,127	20
6,107	27
6,080	20
6,060	23
6,037	37
6,000	20
5,980	27
5,953	23
5,930	30
5,900	20
5,880	25
5,855	17
5,838	25
5,813	23
5,790	20
5,770	20
5,750	27
5,723	

* df is very nearly equal to $p/2\pi$.

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The circulating current in the tuned anode circuit will be Q times this; that is

$$e \times 2.5 \times 10^{-3} \times 180 = 0.45e \text{ amperes.}$$

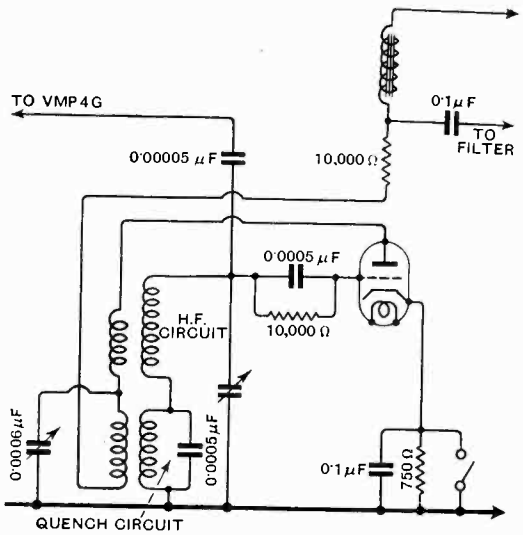

Fig. 6.

Now the e.m.f. injected in series in the super-regenerator grid circuit will be

$$M\omega \times 0.45e \text{ volts}$$

that is, approximately,

$$0.45e \times .3 \times 10^{-6} \times 2\pi \times 14.3 \times 10^{6} = 12.1e$$

The output pentode grid voltage will be the product of the above voltage, the modulation percentage, P, the mutual conductance of the triode hexode (which was measured) and the L.F. anode impedance, *i.e.*,

$$12.1e \times 40\% \times P \times 1.7 \times 10^{-3} \times 20 \times 10^{+3}$$

To produce 1/2 volt across the speech coil this quantity can be equated to approximately 2 volts. This gives, with 20 μV. input

$$P = 606$$

which is astonishingly close to the figure for P ($P = 653$) given in Table I, from which some of the multiplying factors were taken.

Let us now turn to the possibility of application of super-regeneration to wavelengths other than that of Table I, namely, 21 metres.

Table III was obtained from expressions (28) and (30) of the theory.

Before examining Table III, it will be necessary to explain the choice of values of R_m given. The value of tuning condenser used for most domestic broadcast receiver work is approximately fixed owing to quantity production, and its attendant standardisation. This fact immediately fixes the value of the inductance to be used when covering a given wavelength band. Table III gives the normal constants used over 3 normal wavelength bands. Now the quench frequency is a constant for all bands, except, possibly, for the television band where the sidebands are very broad if a reasonable image is desired; therefore one-half of the quench period $\frac{\pi}{p}$ is a constant.

Now Table I, columns 1 and 10, indicates that at 14 megacycles per second, *which means with an inductance* of 1.6 μH, the minimum resistance compatible with stability is 0.187 ohms, this makes the *mean* time constant of the circuit,

$$\theta, \text{ equal to } \frac{\pi \times 1.6 \times 10^{-6}}{0.187}$$

or $$\theta = 27\mu \text{ seconds.}$$

One-half of the quench period is

$$\frac{\pi}{p} = \frac{\pi}{2\pi \times 25{,}000} = 20\mu \text{ seconds.}$$

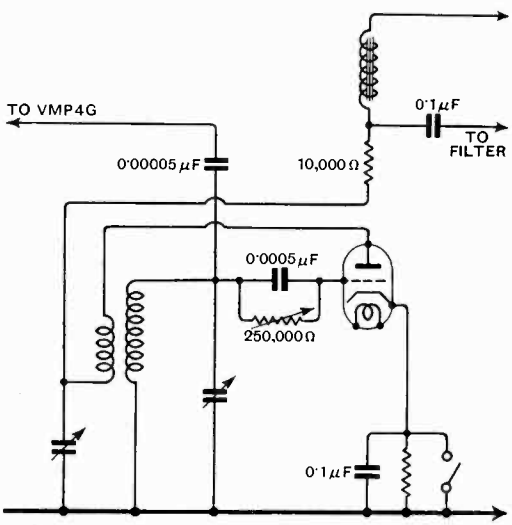

Fig. 7.—*This circuit oscillates at quench frequency when the grid condenser and leak are appropriately chosen. Very little control latitude, but works well.*

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So that actually

$$\frac{\pi}{p} - \theta = -7\mu \text{ seconds.}$$

This means that the initial oscillation is reduced only to less than $\frac{1}{2.7}$th of its initial value when the circuit is again becoming negatively damped. The above considerations give a practical value to the ratio $\frac{R_m}{L}$ at the limit of stability. For high amplification and narrow band-width it is obviously desirable to operate as near the limit as possible. Assuming that with great care a circuit could be constructed which would be stable with an L of 1.6 μH. and an R_m with as low a value as 0.101 ohms instead of 0.187 ohms, we should have an $\frac{R_m}{L}$ ratio of 63,000, this ratio being a constant for the quench frequency of 25 kc/s. The other value of $\frac{R_m}{L}$ in Table III was taken at the

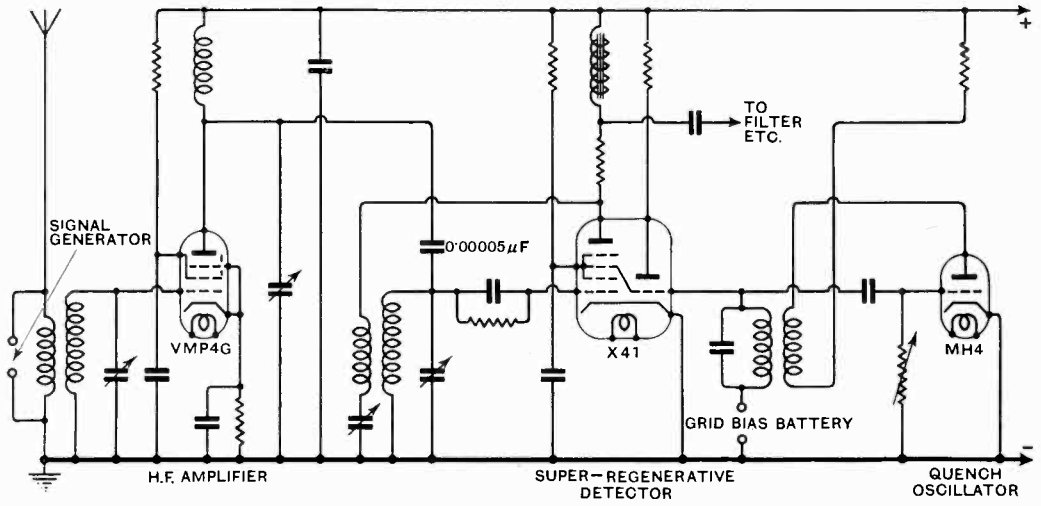

Fig. 8.

TABLE III.

R_m	0.044	0.175	0.101	0.400	11.3	45	f in Mc/s.	L in μH.	
P	4,830	1,330					44	0.7	Television band.
BW kc/s ..	91	332					44	0.7	
P			1,538	423			14	1.6	Short Wave Band.
BW kc/s ..			91	332			14	1.6	
P			658	182			6	1.6	
BW kc/s ..			91	332			6	1.6	
P					110	30.2	1	180	Medium Wave Band.
BW kc/s ..					91	332	1	180	
$R_m/_L$ ..	63,000	250,000	63,000	250,000	63,000	250,000			

Band Widths (BW) are for 10 times down.

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other extreme, that is, with as large an R_m as was obtainable with the circuit of Fig. 8. This gave high stability and low amplification.

Turning now to Table III, we can see at a glance what amplification and what selectivity we could reasonably expect in each of the 3 wave-bands shown. The best figures are those for 44 megacycles/second. These figures, however, would be considerably reduced if the quench frequency were raised—and this raising would be necessary for good quality images, as the quench frequency would have to be outside the pass band, that is, outside the side bands, if a powerful image of quench frequency were to be avoided. The figures for the other bands need no comment ; they should be compared with values obtainable with an adjustable reaction detector.

B. Conclusions

The general conclusions are :—

(*a*) Super-regeneration cannot be made to produce a band-width as low as 10 kc/s at 10 times down at any carrier frequency, unless selection be done at a frequency different from that of the super-regenerative circuit ; this being practically independent of the number of H.F. amplification stages prior to the super-regenerative circuit. The reason for this is that no ordinary amplifier circuit can be made to be completely a one-way device, with the result that some quench voltage will always be present in any H.F. stage, prior to, or after a super-regenerative stage. If the H.F. stage be made highly selective—which means also, highly sensitive, then the small amount of quench voltage present will be sufficient to cause it to super-regenerate, and its selectivity will immediately be lost.

(*b*) Super-regeneration possesses an amplification which, theoretically, is no better than that of an ordinary reaction stage ; in practice, however, it can be more stable (and less selective) for an equivalent amplification and therefore does actually present a slight gain over an ordinary reaction detector. The selectivity being lower, tuning is somewhat less dependent on reaction.

(*c*) If a wave-band is to be covered, reaction and quench voltage must both be controlled for every $\frac{L}{C}$ ratio over the band.

(*d*) Super-regeneration favours high frequencies and becomes useless at frequencies below about 6 Mc/s.

(*e*) Super-regeneration can present a high amplification with low selectivity—a property not possessed by an ordinary tuned circuit associated with a valve.

(*f*) Super-regeneration would have its real value as a fixed frequency detector in, for example, a double super-heterodyne set, wherein the signal frequency would be heterodyned to say, 1 Mc/s, selected on a high "*Q*" intermediate frequency stage, and heterodyned again to, say, 30 Mc/s, super-regenerated, detected, and amplified at low frequency (*QST*, Dec. 1935).

(*g*) Selection cannot be obtained after super-regeneration, as if an interfering station is super-regenerated with the desired signal it becomes quite mixed and modulated with it, so much so that any attempt at separation afterwards would be fruitless.

(*h*) Super-regeneration renders neighbouring highly selective receivers unselective in two ways. Firstly, a super-regenerator is a transmitter for approximately one-half of each quench period—which means that the wave-band of a nearby super-heterodyne receiver is covered with a fundamental, plus harmonics, second channels, and super-regenerative multiple resonance signals. Secondly, if the neighbouring set has a tuned radio frequency circuit with almost critical reaction, it will super-regenerate in synchronism, for the reason given in conclusion (*a*).

(*i*) Super-regeneration presents an automatic volume control action, in that when the signal becomes very strong the super-regenerator will saturate during the negative half of the quench resistance period. While this action might be of use, it must necessarily introduce distortion of the low-frequency modulation of the carrier frequency.

(*j*) It is frequently claimed that super-regeneration is remarkably free from damped wave and transient interference. This is true only if the input signal to be received is sufficiently strong to pass the super-regenerative A.V.C. threshold and saturate the super-regenerator. This condition, however, would introduce considerable distortion as explained in conclusion (*i*). This distortion might be tolerated in certain cases, but not, it is believed, in the case of ordinary

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broadcast receivers. Actually, a special type of transmission should be used if the receiver is to be operated under the above conditions. We wish to make it quite plain, here, that the ordinary type of super-regeneration, in which the anode current of the super-regenerator valve is assumed to be always proportional to the incoming signal and the local oscillation always considerably damped before the commencement of the following quench period, does not present any unusual interference suppressing properties.

(*k*) The choice of quench frequency results from equation (28) of the theory which gives the amplification or "*Q*" of the super-regenerative circuit as

$$P = \frac{L\omega}{R_m} I_0\left(\frac{R_m}{2Lp}\right)$$

where L is the H.F. circuit inductance (super-regenerative grid circuit inductance)

ω is the H.F. pulsation

R_m is the amplitude of quenching resistance.

p is the quench pulsation

I_0 is a modified Bessel function of the first kind and zero order.

Now the function $I_0\left(\frac{R_m}{2Lp}\right)$ which is shown graphically in the theory report is very similar in form to an exponential curve

$$y = e^x$$

Very approximately, then, we can write

$$P = \frac{L\omega}{R_m} e^{\frac{R_m}{2Lp}}$$

(This formula must not be used for calculation purposes.)

It will be seen from the above that for a given L, R_m, and ω, p must be as small as possible to give a large P. From this, p was chosen as near to the low-frequency range as possible. If for any reason p were taken rather large, R_m would have to be increased to unattainable values. (Armstrong in his original papers believed that P increased as the square of the ratio $\frac{\omega}{p}$. David believed, in his theory in the *Onde Electrique*, that P increased as the ratio $\frac{\omega}{p}$, in some manner. Ataka found an optimum $\frac{\omega}{p}$ ratio at a given ω and a given direct anode voltage of the super-regenerator. We believe that there is no optimum $\frac{\omega}{p}$ ratio.)

The above conclusions indicate that super-regeneration might be used

(1) In the case of small, simple receivers, for high amplification coupled with stability and low selectivity—the latter having possible military uses for "searching," or ultra short wave working, such as blind landing of aircraft on 9 metres.

(2) In the case of large receivers as a high gain stable detector as suggested in conclusion (*f*).

(3) High definition television systems on ultra short waves where low selectivity is essential.

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The author also wishes to express his thanks to Electric and Musical Industries Limited for kind permission to publish this work.

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The Physical Society's Exhibition

THE twenty-eighth annual exhibition of scientific instruments and apparatus, arranged by the Physical Society, will be held at the Imperial College of Science and Technology, Imperial Institute Road, South Kensington, London, S.W.7, as follows: Tuesday, January 4th, 2.30 to 9 p.m. Wednesday, January 5th, 4 to 9 p.m. Thursday, January 6th, 2.30 to 9 p.m.

Admission to the exhibition is by ticket only. Members of Institutions and Scientific Societies may obtain tickets from their Secretaries; tickets may also be obtained from the Exhibition Secretary, 1, Lowther Gardens, Exhibition Road, S.W.7.

The February issue of *The Wireless Engineer* will contain a descriptive report of the exhibits of interest to wireless engineers.

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Loud Speaker Reproduction of Continuous-Spectrum Input*

By F. H. Brittain and E. Williams

(*Communication from the Staff of the Research Laboratories of The General Electric Company, Limited, Wembley, England*)

THE discrepancies between the results of response measurements and of listening tests on loud speakers are well known. The existing methods of loud speaker response measurement employ a pure sine wave electrical input to the loud speaker, sometimes with frequency modulation or "warble." This single tone input method does not necessarily indicate the behaviour of the loud speaker when excited by multiple tones of varying amplitude, of the type normally encountered in music and speech. Further, the usual steady state measurements give little or no indication of the effect of transients. To go to the other extreme the input would contain all frequencies simultaneously. Measurements on loud speakers fed from such an input would then be made under conditions approximating to those imposed by the normal reproduction of speech and music. Tests have been carried out to determine the feasibility of this method and the results have been compared with those of the more normal methods of test. This comparison has shown relatively little difference in response curves obtained by the two methods. Certain practical advantages of the new method have, however, been found.

In the usual method of measurement the input of the single frequency required is applied to the loud speaker and the resultant sound is measured. This has the disadvantage that the resultant sound may or may not be entirely of the input frequency. The basis of the new method is the effective application of all frequencies simultaneously to the loud speaker, and the selection and measurement of the required frequency in the resultant output. In practice this "Continuous Spectrum" of frequencies is obtained by utilising the random movement of electrons in a resistance or thermionic valve, and, after linear amplification, applying the amplified noise-voltage to the loud speaker.

In analysing the acoustic output of the loud speaker it is not possible to measure the output at one frequency only, because of the finite band-width of any actual analyser, however selective. The finite band-width gives rise to the effect that the indication of the analyser fluctuates about a mean value,

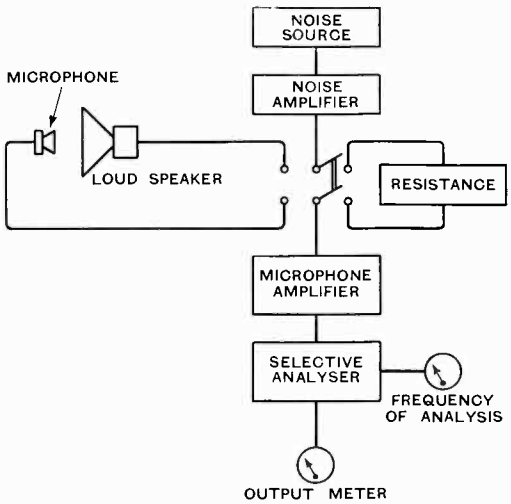

Fig. 1.

which value is assumed here to be a measure of the average energy contained in the frequency band accepted by the filter. The sound output at any one frequency is the sum of that due to the input components of that frequency and to distortion of input components of other frequencies.

The sound is detected by a calibrated microphone whose output is amplified and fed to a selective analyser. Fig. 1 shows a

* MS. accepted by the Editor, May, 1937.

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schematic diagram of the apparatus. After selection, the varying amplitude of the energy in the selected frequency band makes it necessary to use an output meter arranged to give average values over a finite time. The aim is to measure the loud speaker on an input representative of mean conditions over an infinite time. The random nature of the input conditions permits ultimately the occurrence of any type of transient whatsoever, and even steady state conditions for a finite time. The averaging time of the meter must be sufficiently long to ensure that the reading is not unduly influenced by exceptional transient conditions.

The selectivity of the analyser need be made only sufficiently great to preserve the finest irregularities of interest in the response curve of the loud speaker. If the band width of the analyser is unduly small its sensitivity would be very restricted, since the mean voltage in any frequency band is proportional to the square root of the band width. It is interesting to note that if the band width is made infinite, that is with an aperiodic measuring instrument instead of an analyser, the mean output will indicate directly the average sensitivity of the loud speaker. This suggests the use of a weighted noise-meter to give rapid measurements of the men loudness of a loud speaker.

Correction for frequency-distortion of a continuous spectrum input can always be applied, in the form of a function of frequency, characterising the distorting transducer. Thus frequency distortion in the measuring apparatus (microphone and amplifier) does not invalidate the results, providing a correction is applied in the form of the response curve of the microphone and amplifier. The microphone and amplifier in question were a set used for routine tests on loud speakers and caused only slight frequency distortion.

Correction for non-linear distortion of a continuous spectrum input cannot be applied by multiplying the distribution by a function of frequency characterising the non-linear transducer. (This is easily seen by considering a single sinusoidal input.) Thus the microphone and amplifier must be free from non-linear distortion. This was true of the particular microphone and amplifier used.

Since a non-linear transducer cannot be characterised by a function of frequency which on multiplication with the distribution curve of the input will give the distribution curve of the output, all that can be stated about the non-linear properties of the loud speaker is the distribution of the output for some arbitrary distribution of the input. It is convenient to choose a uniform distribution of input, so that the information can be given in one curve instead of two.

The input noise was generated by shot effect in a saturated diode, and after amplification was fed to a non-inductive resistance for measurement. Fig. 2 shows the distribution of energy in the spectrum in such a resistance connected in the microphone circuit, as indicated by the measuring equipment. The attenuation of high frequencies shown in this curve was due to the capacity of the cable connecting the noise amplifier, which was in a separate screened room, to a non-inductive resistance at the normal loud speaker position. Simple correction has been made for this frequency distortion. Frequency selection was made by means of a beat frequency type wave analyser whose oscillator frequency was always so chosen as to give a side band of fifty kilocycles which is the filter frequency.

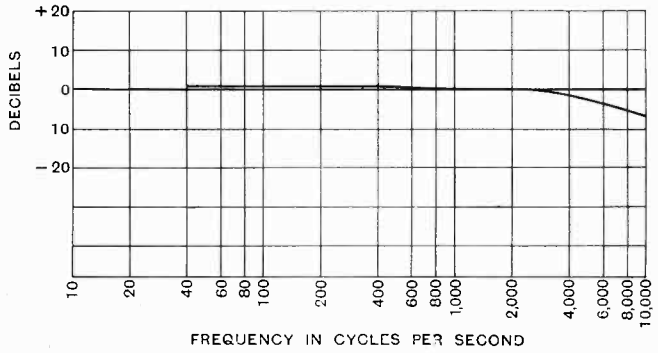

Fig. 2.—*Distribution of energy in non-inductive resistance.*

For a direct comparison of this method and the orthodox single tone method, measurements were carried out in a heavily

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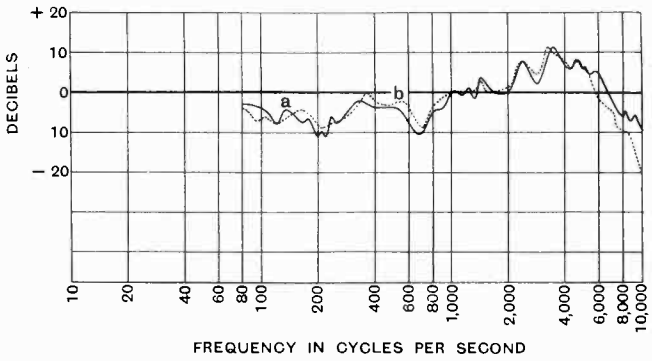
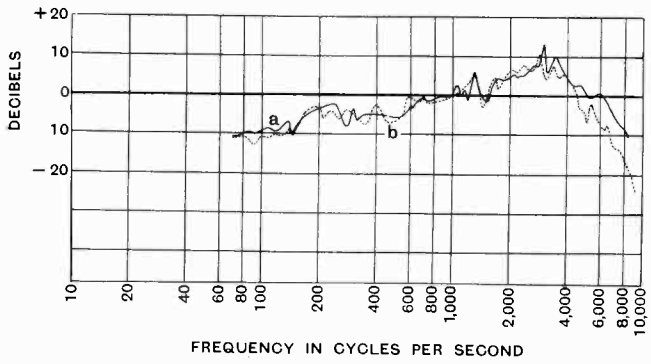
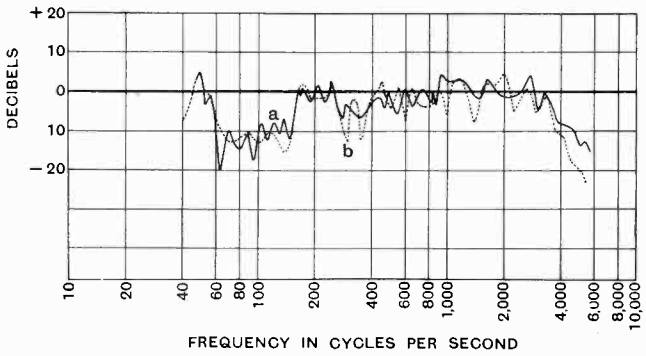
lagged room. All the measurements were carried out with the microphone on the axis of the loud speaker and at distances ranging from 30 to 275 cms. Fig. 3 shows this comparison for a loud speaker in an infinite baffle and Fig. 4 for another loud speaker mounted in a cabinet. In the orthodox method the amplitude of the voice-coil current was maintained constant, while in the new method the distribution of energy was uniform throughout the spectrum (apart from the slight correction mentioned above). Orthodox measurements employing a warble tone were used to measure the response of a loud speaker in an ordinary room; these were compared with the results of the noise analysis methods in the same room. Fig. 5 shows this comparison for a loud speaker mounted in a cabinet in a typical living room. Some of the irregularities in the response curve obtained by the orthodox method are known to be due to the effect of standing waves in the room, though this effect has been reduced by the use of a warble. It should be particularly noted that these irregularities do not occur in the curve obtained by the noise analysis method. As a further check on this feature a response curve was taken by the noise analysis method in a room so live that no results of practical value could be obtained in it even by the use of a normal warble tone. The response curve so obtained is compared in Fig. 6 with the orthodox response curve of the same loud speaker and cabinet measured in a heavily lagged room. This agreement between results obtained in ideal conditions on the one hand and abnormally bad surroundings on the other is very striking. Fig. 7 shows the response curve of an overall



(Above) Fig. 3.—*Loud speaker (infinite baffle) in heavily lagged room. Steady tone, full line; noise analysis, dotted line.*



(Left) Fig. 4.—*Loud speaker in small table cabinet in heavily lagged room. Steady tone, full line; noise analysis, dotted line.*



(Below) Fig. 5.—*Loud speaker in small cabinet in living room. Orthodox warbled tone, full line; noise analysis, dotted line.*

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radio receiving system as measured at the position of a listener's ear in a living room, (*a*) by the orthodox method using a warble tone and (*b*) by the noise analysis method. The absence of room irregularities in the noise analysis curve is apparent, though the detail of the loud speaker response is preserved.

All the above comparisons indicate fair agreement between the results of the orthodox method and the noise analysis method of measurement. The following are some of the major discrepancies between the results of the two methods. Firstly, response curves taken by this method have been found to be freer from irregularities due to room effects than even the response curves

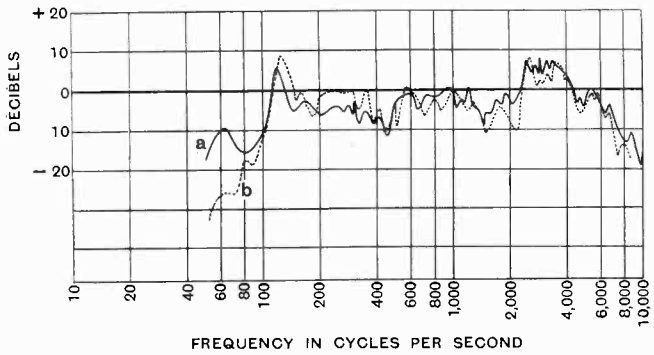


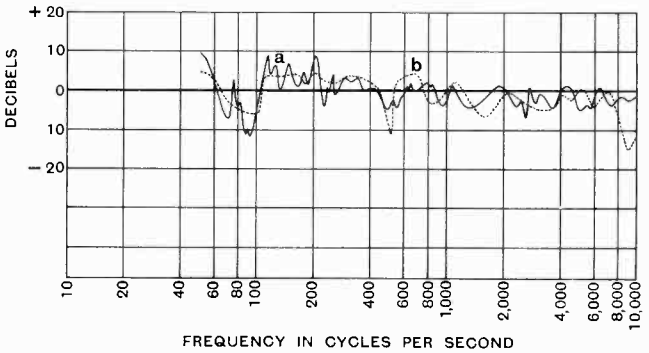
Fig. 6.—*Steady tone, lagged room (small cabinet), full line; noise analysis in live room (small cabinet), dotted line.*

(Right) Fig. 7.—*Overall response of radio receiving system measured at the ear of observer in a living room. Orthodox warbled tone, full line; noise analysis, dotted line.*

obtained by the warble tone method as may be seen in Figs. 4, 5, 7. Now if the harmonic analyser were infinitely selective, and capable of resolving a single frequency, it would indicate the R.M.S. value of the pressure variations at the microphone due to the application of that frequency alone to the room, with its resulting standing waves. Owing to its finite band-width, however, the analyser will indicate the pressure variations at the microphone due to the application of a finite portion of the noise spectrum. By averaging the energy in this finite portion of the spectrum, smoothing of the curve is accomplished in a way similar to but more effective than that of the warble-tone method, since the latter effectively averages the response at a finite number of frequencies, whereas the former averages the response over the frequency band.

Secondly, a type of discrepancy which is liable to occur between curves taken by the orthodox and the noise analyser methods is that shown on the low frequency side of Fig. 6, where the orthodox curve shows a peak at a frequency equal to half the main resonance frequency. This peak is due to the presence of second harmonic in the output of the heterodyne oscillator used for the steady state measurements. It will be realised that owing to the high efficiency of the loud speaker at the bass resonance and its low efficiency at frequencies below this, only a very small harmonic content is required to produce this effect.

Thirdly, Fig. 6 also shows an increase in output of the loud speaker at about twice the frequency of the bass resonance when measured by the noise analysis method. The output



at this frequency is due to direct reproduction of an input of this frequency, together with distortion products of sub-multiple frequencies, in particular, second harmonic distortion of an input of half this frequency. Harmonic measurements on this particular loud speaker

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indicate that the second harmonic content is greater for frequencies near that of the bass resonance, where also the output is considerable. Thus the output at double the bass frequency is considerably augmented by distortion products. This type of harmonic production is an important factor in loud speaker quality and colours the reproduction of speech and music. The indication of this coloration given by response curves obtained by the noise analysis method is one of its advantages.

Fourthly, the response curves obtained by the two methods differ in the neighbourhood of the high frequency cut-off of the loud speaker, the noise analysis method giving a cut-off lower in frequency. This could be accounted for by a discrepancy between the frequency calibrations of the heterodyne oscillator used in the steady state measurements and the wave analyser used in the noise analysis method. These frequency calibrations have been carefully checked, however, and show no such discrepancy. Moreover there is no evidence in the response curves of a simple frequency drift at frequencies other than that of the cut-off. In all the figures shown, and in all other measurements made, this discrepancy between the curves in the region of the high frequency cut-off appears to be associated, not with a particular value of frequency, but with that frequency at which the response of the loud speaker finally falls off. Moreover the discrepancy seems to increase with the sharpness of cut-off. It should be noted that harmonic distortion and cross-modulation in the loud speaker would be expected to produce the opposite effect, giving a higher frequency of cut-off by the noise analysis method.

It is of interest to decide whether this effect is characteristic of the loud speakers in question when reproducing this type of input, or whether it is a defect in the apparatus and method of measurement, in which latter case it would appear in all response curves taken by this method. It has been suggested that the discrepancy is a function of the relative sharpness of the cut-off in the loud speaker response curves and of the response curve of the analyser-filter, that is, that the effect is inherent in the apparatus. The fact that the discrepancy does not occur at the low frequency cut-off, however, throws some doubt on this explanation. It is quite conceivable that the effect is, in fact, characteristic of the loud speaker's frequency-response, in so far as the sharp high frequency cut-off modifies the reproduction of transients.

In conclusion, the advantages of this method appear to be that, firstly, it gives a better indication of the performance of the loud speaker in normal use, by including the effects of harmonic, cross-modulation and transient distortion. Secondly, it enables response curves to be obtained in almost any surroundings whilst preserving the full detail in the loud speaker response curve, which normally is masked by the devices employed to remove the irregularities due to room effects. This method affords no saving in apparatus, for whilst a heterodyne oscillator and warbling device are dispensed with, a noise source and selective analyser are required.

Correspondence

Letters of technical interest are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Distortion in Negative Feedback Amplifiers.

To the Editor, The Wireless Engineer.

SIR,—On pages 259, 369 and 607 of Vol. XIV of *The Wireless Engineer*, letters were published from Mr. Robt. W. Sloane and myself on negative feedback. Subsequently we corresponded with each other on the subject.

I have now revised my calculations on the lines indicated by Mr. Sloane in his letter to me and see that the discrepancy between our results is not due to the difference between the corresponding terms of the Taylor's and the Fourier's series as I stated in my former letter, but to my having neglected the cross modulation which will, in fact, occur between the different harmonics if they are fed back in an amplifier with distortion. I must therefore fully admit the possibility of the third, fifth or any other harmonic being increased by negative feedback.

On the other hand, as this increase is due only to the back-fed harmonics which themselves are substantially minor to the fundamental, and, as this secondary distortion is diminished, as well as the primary, proportionally with the applied degeneration, I think that under normal conditions negative feedback will not spoil the performance of the amplifier to which it is applied.

For example, let us compare the content of

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harmonics at the output of an amplifier, both before and after the application of negative feedback, which amplifies an input swing δe without phase distortion to an output

$$\delta E = \left[\frac{dE}{de}\right]_0 \delta e + \tfrac{1}{2}\left[\frac{d^2E}{de^2}\right]_0 \delta e^2 + \tfrac{1}{6}\left[\frac{d^3E}{de^3}\right]_0 \delta e^3$$

If we apply to this amplifier a pure sinewave

$$\delta e = A \sin \omega t$$

we will get at the output :

$$E = \left[\frac{dE}{de}\right]_0 A \sin \omega t + \tfrac{1}{2}\left[\frac{d^2E}{de^2}\right]_0 A^2 \sin^2 \omega t + \tfrac{1}{6}\left[\frac{d^3E}{de^3}\right]_0 A^3 \sin^3 \omega t$$

$$= \left[\frac{dE}{de}\right]_0 A \sin \omega t + \tfrac{1}{4}(1 - \cos 2\omega t) A^2 \left[\frac{d^2E}{de^2}\right]_0 + \frac{1}{24}(3 \sin \omega t - \sin 3\omega t) A^3 \left[\frac{d^3E}{de^3}\right]_0$$

$$= \tfrac{1}{4}A^2\left[\frac{d^2E}{de^2}\right]_0 + \left\{\left[\frac{dE}{de}\right]_0 A + \tfrac{1}{8}A^3\left[\frac{d^3E}{de^3}\right]_0\right\} \sin \omega t - \tfrac{1}{4}A^2\left[\frac{d^2E}{de^2}\right]_0 \cos 2\omega t - \frac{1}{24}A^3\left[\frac{d^3E}{de^3}\right]_0 \sin 3\omega t$$

The proportion of the harmonics will thus be :

$$K_2 = \frac{\tfrac{1}{4}A^2\left[\frac{d^2E}{de^2}\right]_0}{A\left[\frac{dE}{de}\right]_0 + \tfrac{1}{8}A^3\left[\frac{d^3E}{de^3}\right]_0} \approx \frac{\tfrac{1}{4}A^2\left[\frac{d^2E}{de^2}\right]_0}{A\left[\frac{dE}{de}\right]_0} = \frac{A}{4}\frac{\left[\frac{d^2E}{de^2}\right]_0}{\left[\frac{dE}{de}\right]_0}$$

$$K_3 = \frac{\frac{1}{24}A^3\left[\frac{d^3E}{de^3}\right]_0}{A\left[\frac{dE}{de}\right]_0 + \tfrac{1}{8}A^3\left[\frac{d^3E}{de^3}\right]_0} \approx \frac{A^2}{24}\frac{\left[\frac{d^3E}{de^3}\right]_0}{\left[\frac{dE}{de}\right]_0}$$

or inversely :

$$\left[\frac{d^2E}{de^2}\right]_0 \approx \frac{4}{A}\left[\frac{dE}{de}\right]_0 K_2$$

$$\left[\frac{d^3E}{de^3}\right]_0 \approx \frac{24}{A^2}\left[\frac{dE}{de}\right]_0 K_3$$

If we now apply a fraction β of the output at the input as degeneration, we have for the new amplifier according to Mr. Sloane's calculation :

$$\left[\frac{dE}{de}\right]_0^* = \frac{\left[\frac{dE}{de}\right]_0}{1 + \beta\left[\frac{dE}{de}\right]_0}$$

$$\left[\frac{d^3E}{de^3}\right]_0^* = \frac{\left[\frac{d^3E}{de^3}\right]_0}{\left(1 + \beta\left[\frac{dE}{de}\right]_0\right)^4} - \frac{3\left[\frac{d^2E}{de^2}\right]_0^2 \beta}{\left(1 - \beta\left[\frac{dE}{de}\right]_0\right)^5}$$

if we now increase the input from $A \sin \omega t$ to $A^* \sin \omega t = A\left(1 + \beta\left[\frac{dE}{de}\right]_0\right) \sin \omega t$ in order to get the same output as before, the proportion of the third harmonic will be with the same approximation as above

$$K_3^* \approx \frac{A^{*2}}{24}\frac{\left[\frac{d^3E}{de^3}\right]_0^*}{\left[\frac{dE}{de}\right]_0^*} =$$

$$= \left[\frac{A^2\left(1 + \beta\left[\frac{dE}{de}\right]_0\right)^2}{24} \cdot \frac{\left[\frac{d^3E}{de^3}\right]_0}{\left(1 + \beta\left[\frac{dE}{de}\right]_0\right)^4} \cdot \frac{A + \beta\left[\frac{dE}{de}\right]_0}{\left[\frac{dE}{de}\right]_0}\right] - \left[\frac{3\left[\frac{d^2E}{de^2}\right]_0^2 \beta}{\left(1 + \beta\left[\frac{dE}{de}\right]_0\right)^5} \cdot \frac{A^2\left(1 + \beta\left[\frac{dE}{de}\right]_0\right)^2}{24} \cdot \frac{1 + \beta\left[\frac{dE}{de}\right]_0}{\left[\frac{dE}{de}\right]_0}\right]$$

$$= \frac{A^2}{24} \cdot \frac{\left[\frac{d^3E}{de^3}\right]_0}{\left[\frac{dE}{de}\right]_0} \cdot \frac{1}{1 + \beta\left[\frac{dE}{de}\right]_0} - \frac{A^2}{8} \cdot \frac{\left[\frac{d^2E}{de^2}\right]_0^2}{\left[\frac{dE}{de}\right]_0} \cdot \frac{\beta}{\left(1 + \beta\left[\frac{dE}{de}\right]_0\right)^2}$$

If we express this in terms of the proportion of harmonics without degeneration, we get

$$K_3^* \approx \frac{K_3}{1 + \beta\left[\frac{dE}{de}\right]_0} - 2\frac{\beta\left[\frac{dE}{de}\right]_0}{\left(1 + \beta\left[\frac{dE}{de}\right]_0\right)^2} K_2^2.$$

We see that whilst the initial proportion of the third harmonic will decrease by $1 + \beta\left[\frac{dE}{de}\right]_0$, there will appear, according to Mr. Sloane's statement, another part.

For a given K_2 this second part will be 0 for $\beta = 0$ and for $\beta =$. It will have its maximum at $\beta\left[\frac{dE}{de}\right]_0 = 1$, in which case

$$2\frac{\beta\left[\frac{dE}{de}\right]_0}{\left(1 + \beta\left[\frac{dE}{de}\right]_0\right)^2} = 2\frac{1}{2^2} = \tfrac{1}{2}$$

and the additional part is $\frac{1}{2} K_2^2$. For any other value of β it will be less. If we now take for the initial second harmonic of the amplifier without feedback the extremely high value of $K_2 = 20$ per cent., the additional part of third harmonic will be $\frac{1}{2}K_2^2 = \frac{1}{2}\,0.2^2 = 2$ per cent. For $K_2 = 10$ per cent., it will be $\frac{1}{2}\,0.1^2 = 0.5$ per cent.

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If we now consider that an amplifier which generates such a high proportion of second harmonics, will seldom be quite free from third harmonics and that the initial harmonics are diminished in proportion to the applied degeneration, it is hard to imagine a practical case in which negative feedback would do more harm than good.

These practical observations do not, of course, affect the value of Mr. Sloane's statement, which, I denied in my first letter, and I am much indebted to him for having pointed out my error.

In conclusion it can be stated that: negative feedback diminishes all harmonics approximately in the proportion in which the sensitivity of the amplifier is diminished, but owing to distortion and crossmodulation of the back-fed harmonics, this relation is not exact. Fortunately in ordinary amplifiers the difference is only negligible.

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Nr. Budapest, Hungary. (Research Laboratory, Tungsram Works).

To the Editor, The Wireless Engineer.

SIR,—Considering the literature which has been written on negative feedback, some of which appeared recently in your esteemed journal [1, 2, 3] I should like to point out some facts which as far as I know have been neglected.

The negative feedback amplifier was treated alone without considering the harmonic distortion of the preceding valve amplifier. The application of negative feedback to a valve circuit decreases the amplification of the valve. Therefore to obtain the same output from the valve with feedback as without, we must increase the amplification of the preceding stage—the corresponding increase in the harmonic distortion may exceed the decrease obtained by providing negative feedback, so that the total harmonic distortion may be increased.

Let e be the e.m.f. of the input of the preceding stage, u, the p.d. of the output of the same, U, the p.d. of the output of the final stage, again e', u', V', the correspondong values for the negative feedback case. Using the conventional method of deriving u, from e, V, from u, we may write :

$$u = a_1 e + a_2 e^2 +$$
$$U = \alpha_1 u + \alpha_2 u^2 + \ldots = \alpha_1 a_1 e + (\alpha_2 a_1^2 + \alpha_1 a_2) e^2 + \ldots$$

and for the negative feedback case :

$$u' = a_1 e' + a_2 e'^2 + \ldots$$
$$V' = \frac{\alpha_1}{1 + \alpha_1 \beta} u' + \frac{\alpha_2}{1 + \alpha_1 \beta} u'^2 + \ldots$$
$$= \frac{\alpha_1 a_2}{1 + \alpha_1 \beta} e' + \left(\frac{\alpha_1 a_2}{1 + \alpha_1 \beta} + \frac{\alpha_2 a_1^2}{1 + \alpha_1 \beta} \right) e'^2 + \ldots$$

If the output (without harmonics) is to be the same in both cases : $e' = (1 + \alpha_1 \beta) e$; therefore :

$$V' = \alpha_1 a_1 e + \left(\alpha_1 a_2 (1 + \alpha_1 \beta) + \frac{\alpha_2 a_1^2}{1 + \alpha_1 \beta} \right) e^2 + \ldots$$

To take advantage, as far as harmonic distortion is concerned, from negative feedback, we must have:

$$\alpha_1 a_2 (1 + \alpha_1 \beta) + \frac{\alpha_2 a_1^2}{1 + \alpha_1 \beta} < \alpha_2 a_1^2 + \alpha_1 a_2$$

finally :

$$\frac{\alpha_2}{\alpha_1} > \frac{a_2}{a_1} \Big/ \frac{a_1}{1 + \alpha_1 \beta} ;$$

Beyond a certain limit given by the above relation, negative feedback no longer improves the harmonic distortion of the system. I cannot discuss here in more detail this relation. It would be interesting that such curves as those given in previous works [2, 4] giving harmonic distortion of current against output watts, with and without negative feedback, should be traced taking into account the total harmonic distortion as explained above.

I must point out here that in some previous works of mine [5, 6, 7] concerning a non-linear positive feedback, I have obtained better results than those given in the references mentioned above, results that are not restricted by the above considerations. I also have obtained [8] very good results concerning frequency distortion, with positive feedback (negative impedance method).

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(Research Lab. Poltechnic School).
Bucharest, Romania.

1. *Wireless Engineer*, Vol. XIV, p. 259.
2. *Wireless Engineer*, Vol. XIV, p. 409.
3. *Wireless Engineer*, Vol. XIV, p. 597.
4. *Philips' Technique Rundschau*, Sept., 1936, p. 269.
5. *L'onde Electrique*, Vol. XV, p. 469.
6. *Wireless Engineer*, Vol. XIII, p. 131.
7. *Comptes Rendus*, Vol. 201, p. 193.
8. *Wireless Engineer*, Vol. XII, p. 375.

The Battery Book

By H. H. U. Cross. XII + 196 pp. 92 Figs. The Technical Press, Ltd., 5, Ave Maria Lane, London, E.C.4. Price 5/-.

This is an excellent little book. Its subtitle is a Practical Manual on the construction, charging, care and repair of automobile, motor cycle, aviation, electric vehicle, medical and other similar batteries, and there is a foreword by Mr. J. Y. Fletcher, a Director of the General Electric Co. The author states in the preface that the book is written from the popular angle, but that scattered throughout the pages will be found a measure of scientific information, so stated that the general reader may assimilate it without effort. The arrangement of the material is based upon the author's book in French on the same subject which was recently published in France and Belgium. The first chapter deals with dry and other primary batteries and the subsequent chapters deal with various types of cells, lead, zinc, halogen and alkaline, their construction, operation and applications. The author is evidently an authority both on the practical and theoretical sides of the subject, and the material is arranged and presented in a very readable form. It is a book which may be recommended not only to all those who are primarily interested in accumulators, but also to every student of electrical engineering. G. W. O. H.

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Some Properties of Negative Feedback Amplifiers*

By L. I. Farren, Wh.Sch., A.C.G.I., D.I.C.

(Communication from the Staff of the Research Laboratories of The General Electric Company, Limited, Wembley, England)

SUMMARY.—This paper deals with a subject which is of increasing interest to communication engineers. Various methods of applying negative feedback to thermionic amplifiers are discussed, together with the modifications to the amplifier characteristics produced thereby.

Unwanted phase shifts at very high and very low frequencies will often cause a feedback amplifier to oscillate, if the amount of feedback applied is large; methods of design are given, whereby the maximum possible amount of feedback may be applied without causing self oscillation.

The effect of negative feedback on harmonic distortion is discussed with reference to the case of an amplifier, the output valve of which has a quadratic relationship between grid voltage and anode current.

Contents

1. Introduction.
2. Elementary Theory.
3. Methods of applying negative feedback.
4. Phase Shift and instability.
5. Method of proportioning the stages.
6. Method of subsidiary feedback.
7. Non-linear distortion in negative feedback amplifiers.

1. Introduction

ALTHOUGH the principle of negative feedback has been known for many years, it required the development of the modern high gain valves to make it useful. It then became apparent that the principle was of great importance, for the development among other things of Carrier Telephony, and in 1934 H. S. Black [1] wrote a paper which described this application. Prior to Black's publication, a paper was written by H. Nyquist [2] on the general theory of regeneration; at the time it appeared to be of mathematical interest only with very little practical application, but Peterson, Kreer and Ware [3] have since shown that amplifiers employing negative feedback obey exactly the laws derived by Nyquist.

Since these publications appeared, others have been written dealing with certain aspects of the subject, including in some cases design details of amplifiers for special purposes.†

* MS. accepted by the Editor, April, 1937.

† References 12, 13, 14 and 15 refer to publications which have appeared since MS. was accepted.

However, many properties of negative feedback amplifiers which might be of use to prospective designers, have been dealt with in far too general a manner to be converted easily into practical figures.

It is the purpose of this article to describe certain properties of negative feedback amplifiers and show how these properties may be utilised.

2. Elementary Theory[1]

Fig. 1 shows a schematic diagram of an amplifier with negative feedback applied.

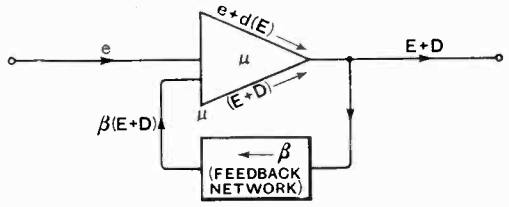

Fig. 1.—*Schematic diagram of amplifier and feedback network.*

The terms have the following significance:

e = Signal input voltage.

μ = Output voltage [excluding $d(E)$] / Voltage on the first grid.

E = Signal output voltage.

β = Voltage fed back to first grid. / Output voltage.

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$d(E)$ = Distortion voltage generated in amplifier.

D = Distortion voltage in the output.

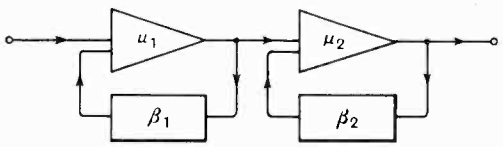
$$\therefore E + D = \mu e + d(E) + \mu\beta[E + D]$$

$$\text{or } E + D = \frac{\mu e}{1 - \mu\beta} + \frac{d(E)}{1 - \mu\beta} \quad \ldots \quad (1)$$

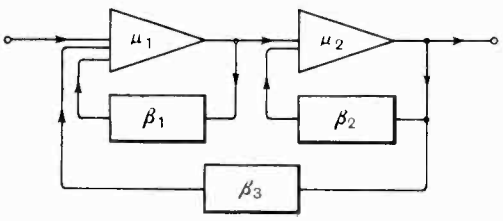
Hence by the application of negative feedback, the amplification has been reduced by a factor $(1 - \mu\beta)$ and the distortion $d(E)$ for a given output E has been reduced by the same factor.

Multiple Feedback.

In some cases it is considered preferable, in multi-stage amplifiers, to split the feedback; e.g. as shown in Fig. 2(a) and (b).



(a)



(b)

Fig. 2.—*Multiple feedback.*

In the case illustrated in Fig. 2(a), the overall amplification is given by

$$\mu = \frac{\mu_1\mu_2}{(1 - \mu_1\beta_1)(1 - \mu_2\beta_2)} \quad \ldots \quad (2)$$

In Fig. 2(b) the overall amplification is given by

$$\mu = \frac{\left(\frac{\mu_1}{1 - \mu_1\beta_1}\right)\left(\frac{\mu_2}{1 - \mu_2\beta_2}\right)}{1 - \beta_3\left(\frac{\mu_1}{1 - \mu_1\beta_1}\right)\left(\frac{\mu_2}{1 - \mu_2\beta_2}\right)} \quad \ldots \quad (3)$$

$$\text{or } \mu = \frac{\mu_1\mu_2}{(1 - \mu_1\beta_1)(1 - \mu_2\beta_2) - \mu_1\mu_2\beta_3} \quad \ldots \quad (4)$$

3. Methods of Applying Negative Feedback

It is of the utmost importance to consider the various methods of applying negative feedback, since a large number of methods are available, each of which endows the amplifier with some new property which may, or may not, be advantageous.

For the moment we will not consider how the feedback voltage is injected into the input circuit, but merely consider the method of tapping it from the output.

Three alternatives are available, which may be designated "current" feedback, "voltage" feedback and "bridge" feedback.

"Current" feedback implies that the feedback voltage is proportional to the output current; "voltage" feedback gives a feedback voltage proportional to the output voltage, and "bridge" feedback is a combination of the two.

"Current" Feedback.

Fig. 3 shows a schematic diagram of an amplifier employing "current" feedback.

The feedback voltage is derived across a resistance R_c in series with the load Z. μ represents the numerical value of the voltage amplification from the grid of the first valve to the anode of the output valve which has an internal resistance R_a. The negative sign before μ (Fig. 3) is obtained most readily by having an odd number of amplifying stages.

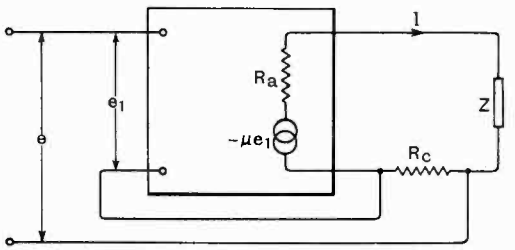


Fig. 3.—*"Current" feedback.*

We have

$$I = \frac{-\mu e_1}{R_a + Z + R_c} \quad \ldots \quad \ldots \quad (5)$$

But $e_1 = e + R_c I$

$$\therefore \quad I = \frac{-\mu e}{R_a + R_c(1 + \mu) + Z} \quad \ldots \quad (6)$$

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If μ is made sufficiently large we have

$$I = -\frac{e}{R_c}$$

Hence the output current, for a given input voltage is sensibly independent of R_a, Z and μ, and depends only on R_c.

At the same time the output impedance has been increased from R_a to $R_a + R_c(1 + \mu)$. By "output impedance" we mean the impedance which would be measured looking back into the output terminals, i.e. the internal impedance of the generator.

This property can therefore be made use of, in some cases, for matching a low impedance valve to a high impedance load, by making

$$Z = R_a + R_c(1 + \mu)$$

"Voltage" Feedback.

Fig. 4 shows a schematic diagram of an amplifier employing "voltage" feedback. The feedback voltage is derived from a tapping on a resistance R shunted across Z; R is considered $\gg Z$.

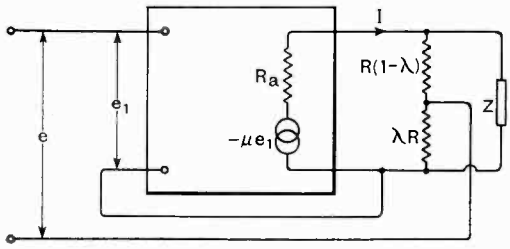

Fig. 4.—*"Voltage" feedback.*

We may write

$$I = \frac{-\mu e_1}{R_a + Z} \quad .. \quad .. \quad .. \quad (7)$$

But $e_1 = e + \lambda ZI$

$$I = \frac{-\mu e}{R_a + Z(1 + \mu\lambda)} \quad .. \quad .. \quad .. \quad (8)$$

If $\mu\lambda$ is $\gg 1$

$$I = -\frac{e}{\lambda Z}$$

$$\text{Output voltage} = IZ = -\frac{e}{\lambda} \quad .. \quad (9)$$

Thus the output voltage for a given input voltage is sensibly independent of μ, R_a and Z and depends only on λ.

At the same time the output impedance has been reduced from R_a to $\frac{R_a}{1 + \mu\lambda}$; this property can therefore be employed for matching a high impedance output valve to a low or medium impedance load.

"Bridge" Feedback.

Fig. 5 shows a schematic diagram of an amplifier employing "bridge" feedback.

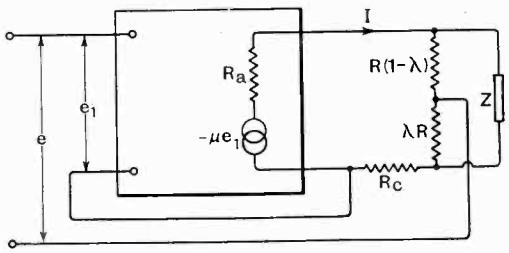

Fig. 5.—*"Bridge" feedback.*

The feedback voltage is the vectorial sum of the voltages across R_c and λR; the voltage across R_c is proportional to the current in the load Z, and the voltage across λR is proportional to the voltage across Z.

Assuming once more that $R \gg Z$, we have

$$e_1 = e + R_cI + \lambda ZI$$

$$\therefore I = \frac{-\mu[e + R_cI + \lambda ZI]}{R_a + R_c + Z}$$

$$\text{or } I = \frac{-\mu e}{R_a + R_c(1 + \mu) + Z(1 + \mu\lambda)} \quad (10)$$

Approximating as before,

$$I = \frac{-e}{R_c + \lambda Z} \quad .. \quad .. \quad .. \quad .. \quad (11)$$

In this case the output current and voltage are independent of μ and R_a, but dependent on Z. The output impedance, from equation (11) is equal to $\frac{R_c}{\lambda}$.

Hence the use of bridge feedback renders the output impedance constant, if R_c and λ are constant, but both the output current and voltage vary with frequency, if Z is frequency dependent.

The extent to which the bridge method of feedback stabilises the output impedance, and one important justification for its use is indicated in the example given below.

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Experimental results are also given. Fig. 6 shows the equivalent circuit of a triode valve, with an amplification factor μ and internal resistance R_a.

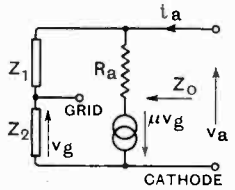

Fig. 6. — *Thermionic valve with anode-grid and grid-cathode impedance.*

Z_1 represents the anode-grid impedance (normally a pure capacity) and Z_2 represents the grid cathode impedance, which includes impedances associated with the preceding amplifier stage.

Assuming that $Z_1 + Z_2 \gg R_a$; if a voltage v_a is applied to the output terminals as shown, a voltage v_g will appear between the grid and cathode through the potentiometer comprising Z_1 and Z_2.

$$\therefore i_a = \frac{v_a + \mu v_g}{R_a}$$

$$= \frac{v_a + \mu\left[\frac{Z_2}{Z_1 + Z_2}\right]v_a}{R_a}$$

$$\therefore Z_0 = \frac{v_a}{i_a} = \frac{R_a(Z_1 + Z_2)}{Z_1 + Z_2(1 + \mu)} \quad .. \quad (12)$$

Z_1 and Z_2 are generally reactive, and only if their phase angles are identical at all frequencies is Z_0 constant. As this condition rarely arises, in general Z_0 will vary with frequency.

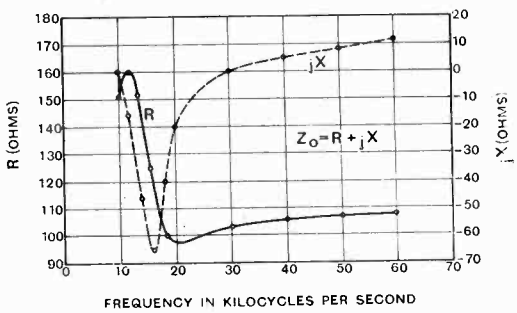

Fig. 7.—*Measured output impedance of amplifier without negative feedback.*

Fig. 7 shows the results of measuring Z_0 on an amplifier with a low impedance triode output valve. The valve fed a transformer of step down ratio 2.45 : 1, and the impedance measurements were taken looking back into the secondary winding.

We see from Fig. 7 that both the resistive and reactive component of Z_0 vary greatly with frequency, the resonance effect at 16 kc/s being due to a coupling choke in the penultimate stage.

On applying "bridge" feedback, with the following values, $R_c = 51\ \Omega$, $\lambda = 1/20$, the results obtained for Z_0 were as shown in Fig. 8.

The resistive component of Z_0 is practically constant and the small reactive component comes from the inherent reactances present in the transformer, which are not eliminated by negative feedback.

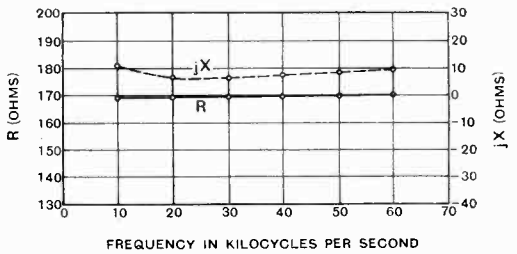

Fig. 8.—*Measured output impedance of amplifier with negative feedback applied.*

The "bridge" method of feedback is the most flexible form, since by making $R_c = 0$ or $\lambda = 0$, we obtain the "voltage" or "current" feedback circuits respectively.

Let us consider the general case when Z is dependent on frequency.

Case 1.—Use of "current" feedback to give constant output voltage.

If, instead of R_c (Fig. 3) we employ an impedance Z_c where $Z_c = KZ$ (K being constant), we have

$$I = -\frac{e}{KZ}$$

$$\text{and } E = IZ = -\frac{e}{K} \quad .. \quad .. \quad .. \quad (13)$$

We may thus obtain constant output voltage with a high output impedance.

Case 2.—Use of "voltage" feedback to give constant output current.

Instead of $R(1 - \lambda)$ and λR in Fig. 4, replace these quantities by KZ and R_1 where $K \gg 1$.

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$$\therefore \lambda = \frac{R_1}{R_1 + KZ} \quad .. \quad .. \quad .. \quad (14)$$

In general μ is very large and λ fairly small so that $\mu\lambda$ is greater than unity.

Hence we may approximate and write equation (14) as,

$$\lambda = \frac{R_1}{KZ} = \frac{K_1}{Z}$$

We thus have

$$I = \frac{-e}{\lambda Z} = \frac{-e}{K_1} \quad .. \quad .. \quad (15)$$

We may thus obtain constant output current with low output impedance.

Case 3.—*Use of bridge feedback to give constant output voltage with constant output impedance.*

Fig. 9 shows a form of circuit which will give the desired result.

The two connections which normally connect the output bridge to the input circuit are joined to the ends of impedances $K\lambda Z$ and KR_c in series and the feedback voltage is developed across $K\lambda Z$. We assume

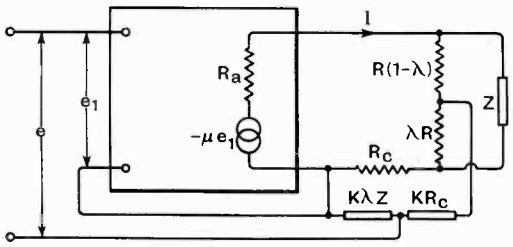

Fig. 9.—*Amplifier with constant output voltage and constant output impedance.*

that $K\lambda Z + KR_c$ is $\gg \lambda R + R_c$, so that the added potentiometer serves as a voltage divider taking no appreciable current.

Rewriting equation (11) we have

$$I = \frac{-e}{\frac{K\lambda Z}{K\lambda Z + KR_c}[R_c + \lambda Z]} \quad .. \quad (16)$$

$$E = IZ = \frac{-e}{\lambda}$$

The output impedance $= \frac{R_c}{\lambda}$ is unaltered, but the output voltage has been rendered independent of Z.

Case 4.—*Use of bridge feedback to give constant output current with constant output impedance.*

This result may be achieved if a circuit is used similar to Fig. 9, except that the arms of the added potentiometer are interchanged.

Rewriting equation (11) we have

$$I = \frac{-e}{\frac{KR_c}{K(R_c + \lambda Z)}[R_c + \lambda Z]} = \frac{-e}{R_c} \quad .. \quad (17)$$

The output impedance $= \frac{R_c}{\lambda}$ is unaltered, but the output current has been rendered independent of Z.

Case 5.—*Use of bridge feedback to give constant voltage output with output impedance = load impedance* (Z).

A circuit which will give the desired result is similar to Fig. 5 except that R_c is replaced by an impedance λZ.

Rewriting equation (11) we have

$$I = \frac{-e}{\lambda Z + \lambda Z} = \frac{-e}{2\lambda Z} \quad .. \quad .. \quad (18)$$

$$E = IZ = -\frac{e}{2\lambda}$$

The output impedance $= \frac{\lambda Z}{\lambda} = Z$, and the output voltage is constant.

This circuit is of use in cases where it is desired to match the output impedance of the amplifier to a load impedance which varies with frequency; this is necessary in many cases where reflections, occurring as the result of an impedance mismatch, must be avoided.

Case 6.—*Use of bridge feedback to give constant current output with output impedance = load impedance* (Z).

Fig. 10 shows a circuit for achieving this result. The new value of λ is $\frac{KR_c}{KZ} = \frac{R_c}{Z}$; K is made $\gg 1$.

Rewriting equation (11) we get

$$I = \frac{-e}{R_c + \frac{R_c}{Z} \cdot Z} = \frac{-e}{2R_c} \quad .. \quad .. \quad (19)$$

The output impedance $= \frac{R_c}{\lambda} = Z$, and the output current is constant.

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Fig. 11 shows an alternative circuit for producing the same result.

$$I = \frac{-e}{\frac{KR_1}{KZ}[\lambda Z + \lambda Z]} = \frac{-e}{2\lambda R_1} \quad \ldots \quad (20)$$

Output impedance $= \frac{\lambda Z}{\lambda} = Z.$

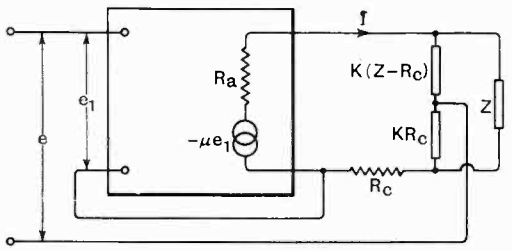

Fig. 10.—*Amplifier with constant output current and output impedance = Z (load impedance).*

4. Phase Shift and Instability

We have seen, from equation (1), that if an amplifier with an amplification factor μ has a fraction of its output fed back to the input circuit, the new amplification factor is given by

$$\mu_F = \frac{\mu}{1 - \mu\beta}$$

If the amplifier comprises a number of stages, each containing reactive components, μ will be some function of frequency. Ignoring the case of D.C. amplifiers, in general for $\omega = 0$ and $\omega = \infty$, $\mu = 0$.

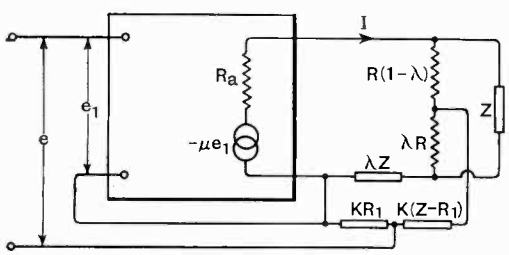

Fig. 11.—*Amplifier with constant output current and output impedance = Z (load impedance).*

Over the desired range of frequencies $\mu\beta$ is made negative, generally by making μ negative. This may be accomplished readily by using an odd number of valve stages, although methods are known whereby an even number of stages may be used.

Since, however, μ is dependent on frequency, it is quite possible for it to be positive and real at certain frequencies. The value of μ under such conditions determines the maximum value of β which can be tolerated. If μ_K is the critical value of μ, for which μ is positive, then if $\mu_K \beta \geqslant 1$ the amplifier is unstable. Actually, Nyquist [2] has shown that this assumption is not rigorously true, but for most cases it is correct.

Thus, if we denote by β_K the maximum value that we can assign to β, we have

$$\mu_K \beta_K = 1.$$

We see therefore that the minimum value obtainable for μ_K determines the maximum value allowable for β_K and hence determines the amount of feedback which may safely be applied.

The problem of designing a circuit to give the smallest unavoidable value of μ_K is far too complicated to be dealt with generally. However, two methods which may be applied in a number of cases will now be given in detail.

5. Method of Proportioning the Stages

This analysis is due to Dr. Werrmann[4].

Let us consider the case of a multi-stage resistance-capacitance coupled amplifier. Each stage of the amplifier would be of the form shown in Fig. 12(a).[11] The symbols have the following meaning.

e = Grid voltage applied to the stage.
g = Mutual conductance.
C_{ac} = Anode cathode capacitance.
R_a = Internal resistance of valve.
R_L = Load resistance.
C_1 = Coupling condenser capacitance.
R_g = Grid cathode resistance of next valve.
C_{gc} = Grid cathode capacitance of next valve.
E = Voltage applied to grid of the next valve.

The capacitance C_{ac} is usually very small ($< 10\mu\mu$F) and has an effect only at high frequencies; hence we can consider it as being effectively in parallel with C_{gc} giving a resultant shunt capacitance

$$C_g = C_{ac} + C_{gc}$$

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In general we are dealing with screen grid or screened pentode valves in which the anode grid capacitance is very small; for this reason it has been ignored.

We may write

$$\frac{E}{e} = -g\frac{j\omega C_1 R_a R_L R_g}{(R_a + R_L - \omega^2 R_a R_L R_g C_1 C_g) + j[\omega R_g (R_a + R_L)(C_1 + C_g) + \omega R_a R_L C_1]} \quad .. \quad .. \quad (21)$$

The expression by which g is multiplied has the form of a complex impedance, and it can be shown that this impedance may be represented in the circuit of Fig. 12(b); R, L and C in parallel form the desired

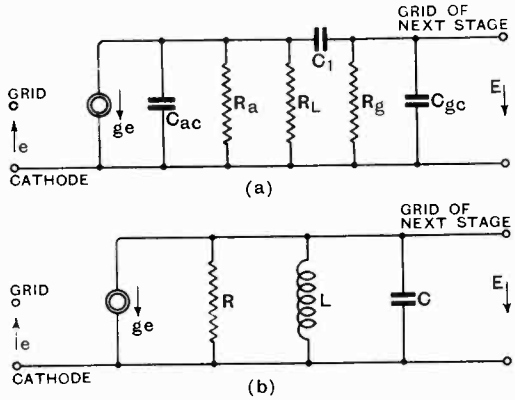

Fig. 12 (a).—*Equivalent circuit of thermionic valve and resistance-capacitance coupling.* (b).—*Circuit which is equivalent electrically to* (a).

impedance. The first conception of a resistance capacitance coupled amplifier as a tuned amplifier was due to Luck.[5] The following relations are true.

$$\left.\begin{aligned} \frac{1}{R} &= \frac{1}{R_a} + \frac{1}{R_L} + \frac{1}{R_g} + \left(\frac{1}{R_a} + \frac{1}{R_L}\right)\left(\frac{C_g}{C_1}\right) \\ L &= C_1 R_g \left[\frac{R_a R_L}{R_a + R_L}\right] \\ C &= C_g \end{aligned}\right\} \quad .. \quad (22)$$

We may now study the effect of proportioning the relative magnitudes of R, L and C.

For a single stage, as shown in Fig. 12(b), the amplifying factor of the stage is given by $\mu = \frac{E}{e}$

$$\therefore \mu = \frac{E}{e} = \frac{-g}{\frac{1}{R} + \frac{1}{j\omega L} + j\omega C} \quad .. \quad (23)$$

Consider the case of an amplifier with "r" stages (not necessarily identical).

We have $\mu = \mu_1 \cdot \mu_2 \cdot \mu_3 \cdot \ldots \cdot \mu_r$.

From equation (23) we may write

$$\mu = \prod_{n=1}^{n=r} \frac{-g_n}{\frac{1}{R_n} + \frac{1}{j\omega L_n} + j\omega C_n} \quad .. \quad (24)$$

By means of equation (24) it is possible to find one or more values of ω at which μ is real and positive; these values of μ have already been called μ_K (critical values).

Any particular case is most easily solved by graphical methods, as analysis would become tedious. Certain special cases may be solved however.

Case 1.—*r identical stages.*

From equation (24)

$$\mu = \left\{\frac{-g}{\frac{1}{R} + \frac{1}{j\omega L}\left(1 - \frac{\omega^2}{\omega_0^2}\right)}\right\}^r \quad .. \quad (25)$$

where $\omega_0^2 LC = 1$

When $\omega = \omega_0$, $\mu = \mu_0 = (-gR)^r$

μ_0 represents the maximum amplification obtainable, and since we normally employ an odd number of stages, μ_0 is negative.

From (25)

$$\mu = \mu_0 \left[\frac{1}{\left\{1 + \frac{R\left(1 - \frac{\omega^2}{\omega_0^2}\right)}{j\omega L}\right\}^r}\right] \quad .. \quad (26)$$

The phase angle of μ may be determined from the phase angle of the denominator of the bracketed expression.

$$\text{Let} \quad \frac{R\left(1 - \frac{\omega^2}{\omega_0^2}\right)}{\omega L} = \tan\phi$$

$$\therefore \mu = \mu_0 \frac{\cos^r \phi}{[\cos\phi - j\sin\phi]^r}$$

$$= \frac{\mu_0 \cos^r \phi}{\cos r\phi - j \sin r\phi} \quad .. \quad .. \quad (27)$$

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With the coupling circuit as shown in Fig. 12(b) ϕ must lie between the limits $-\frac{\pi}{2}$ and $\frac{\pi}{2}$.

Hence $\cos^r \phi$ is always positive.

Hence from equation (27) assuming μ_0 negative, μ is real and positive when

$$\cos r\phi - j \sin r\phi = -1 \text{ or } \phi = \frac{\pi}{r}$$

$$\text{Thus } \mu_K = -\mu_0 \cos^r\left(\frac{\pi}{r}\right) \quad .. \quad .. \quad (28)$$

If β_K is the maximum fraction of the output which may be fed back, we may write

$$\beta_K = \frac{1}{\mu_K}$$

Hence the maximum gain reduction, or linearisation, which we can obtain is given by

$$1 - \mu_0\beta_K = 1 + \frac{1}{\cos^r\left(\frac{\pi}{r}\right)} \quad .. \quad (29)$$

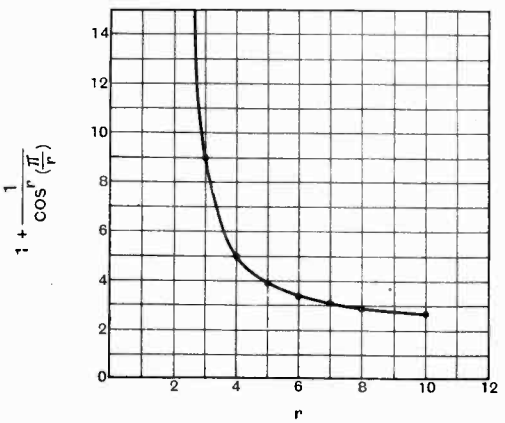

Fig. 13.—*Curve showing the dependence of the maximum possible amount of feedback on the number of stages (r), assuming identical stages.*

We see that the amount of linearisation possible is dependent on r; a curve relating r and $1 + \frac{1}{\cos^r\left(\frac{\pi}{r}\right)}$ is shown in Fig. 13.

With $r = 1$ (case of single stage amplifier), the critical frequency never occurs; with $r = 2$ it only occurs at $\omega = 0$ and $\omega = \infty$, in which case $\mu_K = 0$.

μ_K only becomes real for $r > 2$.

In other words, single stage and two stage amplifiers using a coupling circuit as shown, should never be unstable however much feedback is applied. In practice, of course, such factors as decoupling circuits and unwanted reactive components in the feedback path all cause undesirable phase shifts which may cause instability even in the case of a two-stage amplifier. From Fig. 13, we see that with 3 identical stages ($r = 3$), the maximum degree of linearisation is 9.

By making the 3 stages dissimilar in a definite manner, the maximum degree of linearisation obtained may be increased quite considerably.

Case 2.—The effect of dimensioning on the 3-stage case.

We have seen that the maximum value which $\mu_0\beta_K$ can have in the case of three identical stages is 8. We will now consider the case of three stages dimensioned differently.

Our first assumption is to give each stage the same resonant frequency $\omega_0 = \frac{1}{\sqrt{L_nC_n}}$, but at the same time we allow the quantities $\frac{L_n}{R_n}$ to be different, if necessary, for each stage.

Let us write

$$\omega_1 = \frac{R_1}{L_1}, \quad \omega_2 = \frac{R_2}{L_2}, \quad \omega_3 = \frac{R_3}{L_3}$$

$$\therefore \mu = \prod_{n=1}^{n=3} -g_nR_n\left\{\frac{1}{1 + \frac{R_n}{j\omega L_n}\left(1 - \frac{\omega^2}{\omega_0^2}\right)}\right\} \quad (30)$$

$$= \mu_0 \prod_{n=1}^{n=3} \frac{1}{1 + \frac{\omega_n}{j\omega}\left(1 - \frac{\omega^2}{\omega_0^2}\right)} \quad .. \quad (31)$$

where $\mu_0 = -(g_1g_2g_3)(R_1R_2R_3)$

The critical pulsatance ω_K is determined from the value of ω which makes μ real and positive (μ_K).

This is obtained from a solution of the equation

$$\prod_{n=1}^{n=3}\left\{1 - \frac{j\omega_n}{\omega}\left(1 - \frac{\omega^2}{\omega_0^2}\right)\right\} = A + j \cdot 0$$

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For the imaginary component of the LH expression to be zero,

$$\frac{(\omega_1+\omega_2+\omega_3)\left(1-\frac{\omega^2}{\omega_0^2}\right)}{\omega} = \frac{\omega_1\omega_2\omega_3\left(1-\frac{\omega^2}{\omega_0^2}\right)^3}{\omega^3} \quad .. \quad .. \quad (32)$$

$$\text{or } \sqrt{\frac{\omega_1+\omega_2+\omega_3}{\omega_1\omega_2\omega_3}} = \frac{\left(1-\frac{\omega^2}{\omega_0^2}\right)}{\omega} \quad .. \quad (33)$$

The two values of ω obtained from equation (33) give the upper and lower values of pulsatance at which μ is real and positive. By making ω_0 the same for each stage, for each of these values of ω, μ has the same value.

Substituting (33) in (31) we get

$$\mu_K = \frac{\mu_0}{1-(\omega_1+\omega_2+\omega_3)\left(\frac{1}{\omega_1}+\frac{1}{\omega_2}+\frac{1}{\omega_3}\right)} \quad .. \quad (34)$$

Let us assume, arbitrarily, that two of these pulsatances are fixed, say, ω_1 and ω_3.

Let us suppose that ω_2 may be varied between the limits ω_1 and ω_3; we have to find the values of ω_2 that make the expression $(\omega_1+\omega_2+\omega_3)\left(\frac{1}{\omega_1}+\frac{1}{\omega_2}+\frac{1}{\omega_3}\right)$ a maximum.

As an example, suppose $\omega_3 = 5\omega_1$; Fig. 14 shows the variation of the magnitude of the above expression for values of ω_2 between ω_1 and $5\omega_1$.

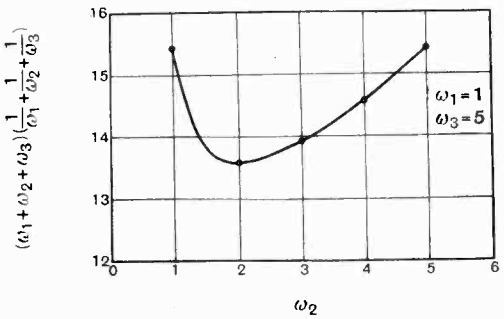

Fig. 14.—*Curve showing the effect of proportioning the stages in a three-stage amplifier.*

We see from Fig. 14 that the maximum linearisation (i.e. minimum value of μ_K) is obtained under the conditions $\omega_2 = \omega_1$ or $\omega_2 = \omega_3$.

Having now decided that ω_2 must equal either ω_1 or ω_3 we may study the effect of varying the ratio $\frac{\omega_3}{\omega_1}$.

Let $\omega_1 = a$, $\omega_2 = a$, $\omega_3 = ma$ where m is any number.

Substituting these values in (34) we get

$$\mu_K = \frac{\mu_0}{1-\frac{(1+2m)(2+m)}{m}} \quad .. \quad (35)$$

The maximum degree of linearisation

$$= 1-\mu_0\beta_K$$
$$= 1-\frac{\mu_0}{\mu_K}$$
$$= \frac{(1+2m)(2+m)}{m} \quad .. \quad .. \quad (36)$$

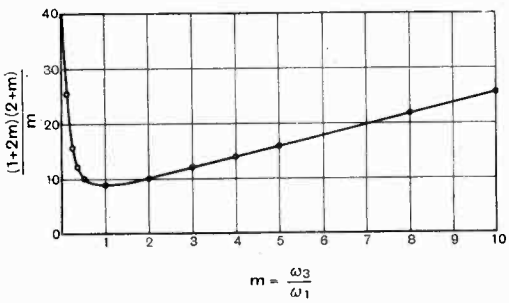

Fig. 15.—*Curve showing the effect of proportioning the stages in a three-stage amplifier.*

It is quite obvious that the same result would be achieved if $\omega_1 = a$, $\omega_2 = ma$, $\omega_3 = ma$.

Fig. 15 shows the variation of

$$\frac{(1+2m)(2+m)}{m}$$

plotted against m; we see that for $m = 1$ (i.e. three identical stages) the value is 9 (compare Fig. 13 for $r = 3$).

Summary of analysis.

From the foregoing we see that in order to be able to apply the maximum amount of negative feedback, the following rules must be adopted.

1. The resonant frequency ω_0 (as defined) must be the same for each stage.

2. If we characterise each stage by a lower pulsatance $\omega_a = \frac{R}{L}$ and an upper pulsatance

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$$\omega_b = \frac{1}{CR}, \quad \omega_0 = \sqrt{\omega_a \omega_b}.$$

In the case of three stages, two of the lower pulsatances ω_a and two of the upper pulsatances ω_b must be equal, whilst the remaining lower and upper pulsatance respectively must be as different from these as possible.

6. Method of Subsidiary Feedback

This method is an alternative to the above for the purpose of allowing the maximum amount of feedback to be applied to an amplifier consistent with stability (6).

In a multi-stage amplifier, at least one of the stages is provided with a subsidiary feedback circuit, adapted to feed back a voltage which, over the working frequency range, is so small that the forward amplification is substantially unaffected. At frequencies outside this range, however, this voltage is increased so as to reduce considerably the gain of the stage and of the amplifier without introducing a phase shift liable to cause instability.

The method is termed subsidiary feedback because the feedback is common to a single stage as distinct from the main feedback circuit which connects the input and output of the whole amplifier.

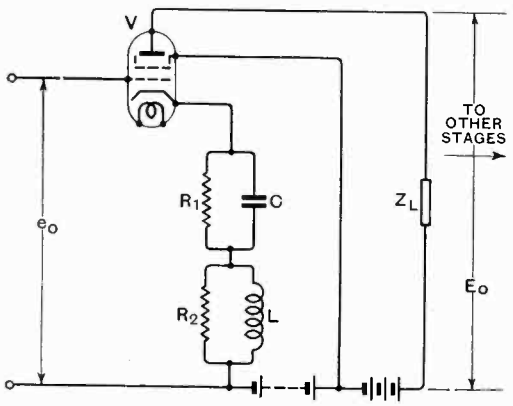

Fig. 16.—*Subsidiary feedback. Single valve with "current" feedback.*

Fig. 16 shows one circuit for achieving the desired result.

The valve V may be assumed to be a screen grid or pentode valve with a load impedance Z_L.

Subsidiary feedback is developed across an impedance in the cathode circuit comprising resistances R_1 and R_2, an inductance L and capacitance C as shown. If the valve constants are μ, R_a and $g = \frac{\mu}{R_a}$, and if the feedback impedance be called Z, we have

$$\left(\frac{E_0}{e_0}\right)_z = \frac{-\mu Z_L}{R_a + Z_L + Z(1+\mu)} \quad \ldots \quad (37)$$

If R_a is $\gg Z_L$ and $\mu \gg 1$, then

$$\left(\frac{E_0}{e_0}\right)_z = \frac{-Z_L}{\frac{1}{g} + Z} \quad \ldots \quad \ldots \quad (38)$$

If there were no subsidiary reaction, Z would be zero and

$$\left(\frac{E_0}{e_0}\right)_{z=0} = -gZ_L$$

$$\therefore \quad \frac{\left(\frac{E_0}{e_0}\right)_z}{\left(\frac{E_0}{e_a}\right)_{z=0}} = \frac{1}{1+gZ} = P + jQ \quad \ldots \quad (39)$$

If μ_z is the modulus of $P + jQ$ and θ the change in phase difference between E_0 and e_0 due to the introduction of Z, then

$$\left.\begin{aligned} \mu_z &= (P^2 + Q^2)^{\frac{1}{2}} \\ \tan\theta &= \frac{Q}{P} \end{aligned}\right\} \quad \ldots \quad \ldots \quad (40)$$

Let C shunted by R_1 be an impedance $A_1 + jB_1$ and L shunted by R_2 be an impedance $A_2 + jB_2$.

$$\therefore Z = A_1 + A_2 + j(B_1 + B_2)$$

$$P = \frac{1 + g(A_1 + A_2)}{[1 + g(A_1 + A_2)]^2 + g^2(B_1 + B_2)^2}$$

$$Q = \frac{-g(B_1 + B_2)}{[1 + g(A_1 + A_2)]^2 + g^2(B_1 + B_2)^2}$$

$$\left.\begin{aligned} \therefore \mu_z &= \left[\frac{1}{[1 + g(A_1 + A_2)]^2 + g^2(B_1 + B_2)^2}\right]^{\frac{1}{2}} \\ \tan\theta &= \frac{-g(B_1 + B_2)}{1 + g(A_1 + A_2)} \end{aligned}\right\} \quad \ldots \quad \ldots \quad (41)$$

By way of illustration, let us take the following values as an example.

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g = 0.008 amps/volt
R_1 = 100 Ω
R_2 = 1000 Ω
C = 1μF
L = 0.5 mH

The following table shows the values of μ_z and θ for values of frequency from 10 c/s to 2 Mc/s.

Frequency c/s.	$A_1 + A_2$	$B_1 + B_2$	Change in Gain. μ_z in dB's.	Phase Shift θ
10	100	0	− 5.1	0
30	100	− 1.92	− 5.1	0
100	100	− 6.27	− 5.1	0
300	96.5	−18.6	− 4.9	4° 48′
700	83.9	−34.7	− 4.5	9° 24′
1,000	71.8	−45.6	− 4.2	13° 0′
1,500	53	−45.3	− 3.3	14° 12′
2,000	38.6	−42.3	− 2.5	14° 30′
3,000	21.9	−31.9	− 1.5	12° 18′
10,000	3.5	15.7	− .2	− 7° 0′
30,000	0.1	88.7	− 1.6	−33° 30′
60,000	34.4	180	− 5.5	−48° 6′
100,000	86.0	284	− 9	−53° 18′
200,000	310	450	−14	−45° 54′
300,000	420	498	−15.8	−39° 54′
500,000	710	452	−17.7	−28° 30′
1,000,000	890	290	−18.6	−16° 0′
2,000,000	975	155.2	−19.1	− 8° 0′

The working range of frequencies would extend from about 3 kc/s to 40 kc/s; over this range the change in gain due to subsidiary feedback is small.

Above this range the decrease in gain is fairly considerable and is not accompanied by a correspondingly large phase shift; in fact, the phase shift actually decreases at high frequencies and becomes zero at a frequency of infinity. In the example chosen, due to the particular values assigned to R_1 and C, the gain reduction at low frequencies is small, but by making $R_1 = R_2$ the gain reduction at very low frequencies will be the same as at very high frequencies.

This method does not modify the fundamental phase shift between E_0 and e_0 due to the phase angle of Z_L, but the main point in its favour is that a gain reduction is obtained with no appreciable increase in the phase shift which would be present if no feedback were applied.

An alternative method is shown in Fig. 17; the circuit is similar in some ways to Fig. 16, the difference lying in the fact that the subsidiary feedback is now of the "voltage" type.

Feedback voltage is applied across the bottom half of a potentiometer shunted across Z_L, consisting of resistances R_1. R_2 and R_3 capacitance C and inductance L,

Assume that Z has the same meaning as before and assume $R_3 + Z \gg Z_L$

$$\therefore \left(\frac{E_0}{e_0}\right)_z = \frac{-gZ_L}{1 + \frac{gZZ_L}{R_3 + Z}} \quad \ldots \quad \ldots \quad (42)$$

and $$\frac{\left(\frac{E_0}{e_0}\right)_z}{\left(\frac{E_0}{e_0}\right)_{z=0}} = \frac{1}{1 + \frac{gZZ_L}{R_3 + Z}} \quad \ldots \quad \ldots \quad (43)$$

From this expression the gain reduction can be calculated if Z_L is known.

At very high frequencies, Z approximates to R_2 and equation (42) becomes

$$\left(\frac{E_0}{e_0}\right)_z = \frac{-gZ_L}{1 + KZ_L} \text{ where } K = \frac{-gR_2}{R_2 + R_3} = \text{constant.}$$

It is possible in practice to make KZ_L large compared with unity, in which case

$$\left(\frac{E_0}{e_0}\right) = \frac{-gZ_L}{KZ_L} = \frac{-g}{K} \quad \ldots \quad \ldots \quad (44)$$

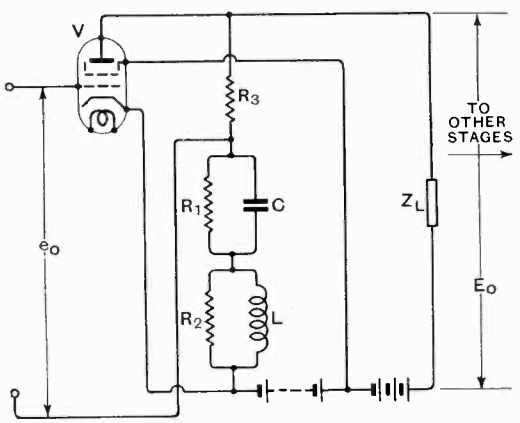

Fig. 17.—*Subsidiary feedback. Single valve with "voltage" feedback.*

Thus, at these high frequencies the voltage E_0 applied to the next stage is approximately 180 deg. out of phase with e_0, irrespective of the phase angle of Z_L; hence it approaches the ideal conditions. Similar reasoning holds for very low frequencies. Thus the arrangement shown in Fig. 17 has the advantage that at very high and very low frequencies it reduces the phase shift which

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would be characteristic of the stage if there were no subsidiary reaction, as well as giving a decrease in gain. Other methods which deal with the subject of improving the stability of feedback amplifiers by control of phase shift are given in references (7), (8) and (9).

7. Non-Linear Distortion in Negative Feedback Amplifiers

In the section on elementary theory we saw that if an amplifier, giving an output distortion voltage $d(E)$ for a given output E, has negative feedback applied to it, then for the same output E the distortion is reduced to $\frac{d(E)}{1-\mu\beta}$.

This result can only be achieved by neglecting "secondary" distortion; in other words, the output distortion voltage which is fed back to the input and amplified is distorted once again and not amplified linearly as Black assumes. Admittedly this effect may be ignored for small outputs, but when the output valve is approaching the overload point e.g. when it is generating over 5 per cent. harmonic, the reduction in harmonic by the application of feedback may be smaller than one would expect theoretically. The rigorous treatment of the general case of distortion in a feedback amplifier has been given by R. Feldtkeller (10).

In the results obtained by Feldtkeller, the output valve anode current-grid voltage characteristic is assumed to be an infinite power series, and expressions are obtained for the equation of the modified characteristic obtained by the application of negative feedback.

If we assume the valve characteristic to be of the form $I_a = a_1 e_g + a_2 e_g^2$, a fairly simple solution can be found.

If current feedback is used, for example, let the value of the feedback resistance be R.

$$\therefore e_g = (e_{g1} - I_a R)$$

where e_{g1} = signal input voltage.

e_g = voltage appearing between grid and cathode.

$$\therefore I_a = a_1(e_{g1} - I_a R) + a_2(e_{g1} - I_a R)^2 \quad .. \quad (45)$$

Solving (45) as a quadratic in I_a we get

$$I_a = \frac{1 + a_1 R + 2a_2 R e_{g1} \pm \sqrt{(1 + a_1 R)^2 + 4a_2 R e_{g1}}}{2a_2 R^2} \quad .. \quad .. \quad (46)$$

Expanding this as a series in e_{g1} and using the symbols $K_1 = 1 + a_1 R$ and $K_2 = 2a_2 R$, we get

$$I_a = \frac{K_1}{K_2 R}\left[\frac{K_2(K_1 - 1)}{K_1^2} e_{g1} + \frac{K_2^2}{2K_1^4} e_{g1}^2 - \frac{K_2^3}{2K_1^6} e_{g1}^3 + \frac{5K_2^4}{16K_1^8} e_{g1}^4 + \ldots\ldots\right] \quad .. \quad (47)$$

Equation (47) gives us the new relationship existing between output current and signal voltage, when negative feedback is applied.

For a given value of fundamental output current we can find the necessary value of input signal and the percentage amplitude of the various harmonics occurring in I_a.

Without feedback, let the input signal voltage be $e_g = e \cos \omega t$ and with feedback let the input signal voltage to give the same fundamental output current be $e_{g1} = e_1 \cos \omega t$.

$$\therefore I_{a_{\omega t}} = a_1 e \cos \omega t \text{ without feedback.}$$

Also $I_{a_{\omega t}} = \frac{(K_1 - 1)e_1 \cos \omega t}{RK_1}$ from (47) with feedback.

$$\therefore a_1 e = \frac{a_1 R e_1}{R(1 + a_1 R)} = \frac{a_1 e_1}{1 + a_1 R}$$

$$\therefore \frac{e_1}{e} = (1 + a_1 R) \quad .. \quad .. \quad .. \quad (48)$$

Thus for the same fundamental output current the input voltage with feedback is $(1 + a_1 R)$ times as great as the input voltage without feedback.

Let us now compare the distortions in the two cases, assuming the same fundamental output current.

Without feedback.

$$I_a = a_1 e \cos \omega t + a_2 e^2 \cos^2 \omega t$$

$$= a_1 e \cos \omega t + \frac{a_2}{2} e^2 (1 + \cos 2\omega t) \quad .. \quad (49)$$

$$\frac{\text{Amplitude of } \cos 2\omega t}{\text{Amplitude of } \cos \omega t} = \frac{a_2 e}{2a_1} \quad .. \quad .. \quad (50)$$

With feedback.

$$I_a = \frac{K_1}{K_2 R}\left[\frac{K_2(K_1 - 1)}{K_1^2} e_1 \cos \omega t + \frac{K_2^2}{2K_1^4} e_1^2 \cos^2 \omega t - \frac{K_2^3}{2K_1^6} e_1^3 \cos^3 \omega t + \frac{5K_2^4}{16K_1^8} e_1^4 \cos^4 \omega t \ldots\right]$$

$$\therefore I_a = \frac{K_1}{K_2 R}\left[\left\{\frac{K_2^2}{4K_1^4} e_1^2 + \frac{15K_2^4}{128K_1^8} e_1^4 + \ldots\right\}\right.$$

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$$+ \cos \omega t \left\{ \frac{K_2(K_1 - 1)}{K_1^2} e_1 - \frac{3K_2^3}{8K_1^6} e_1^3 + \ldots \right\}$$
$$+ \cos 2\omega t \left\{ \frac{K_2^2}{4K_1^4} e_1^2 + \frac{5K_2^4}{32K_1^8} e_1^4 + \ldots \right\}$$
$$+ \cos 3\omega t \left\{ - \frac{K_2^3}{8K_1^6} e_1^3 + \ldots \right\}$$
$$+ \cos 4\omega t \left\{ \frac{5K_2^4}{128K_1^8} e_1^4 + \ldots \right\}$$
$$+ \ldots \ldots \ldots \Big] \quad \ldots \quad \ldots \quad (51)$$

The coefficient of $\cos \omega t$ may quite justifiably be taken as the first bracketed term only, viz. $\frac{K_2(K_1 - 1)}{K_1^2} e_1$

Thus $\frac{\text{Amplitude of } \cos 2\omega t}{\text{Amplitude of } \cos \omega t}$

$$= \frac{\left\{ \frac{K_2^2}{4K_1^4} e_1^2 + \frac{5K_2^4}{32K_1^8} e_1^4 \right\}}{\frac{K_2(K_1 - 1)}{K_1^2} e_1}$$

$$= \frac{K_2 e_1}{4K_1^2(K_1 - 1)} \left[1 + \frac{5K_2^2 e_1^2}{8K_1^4} \right] \quad \ldots \quad (52)$$

For the moment, let us ignore the right-hand expression in the bracket.

$$\frac{\text{Amplitude of } \cos 2\omega t}{\text{Amplitude of } \cos \omega t} = \frac{2a_2 R e_1}{4a_1 R(1 + a_1 R)^2}$$

and since $e_1 = e(1 + a_1 R)$

$$\therefore \quad \text{Ratio} = \frac{a_2 e}{2a_1(1 + a_1 R)} \quad \ldots \quad (53)$$

Comparing this expression with (50), we see that for the same fundamental output current, the second harmonic has been reduced by a factor $(1 + a_1 R)$, i.e. the same amount as the reduction in amplification.

If we now include the second term in the bracket of equation (52) we are really including the effect of secondary distortion. The relative magnitudes of these quantities will best be appreciated by a typical example.

Let $a_1 = .01$, $a_2 = .002$,

$e_g = 1 \cos \omega t$ volts, $R = 900\Omega$

Plotted in the table below are the various harmonic percentages for the same fundamental output current, with and without feedback.

The results obtained on the assumption of no secondary distortion are also included.

	Per cent. Harmonic.		
Frequency Term.	Without Feedback.	With Feedback and neglecting secondary distortion.	With Feedback and allowing partly for secondary distortion.
cos 2 *wt*	10%	1%	1.081%
cos 3 *wt*	0	0	.18%
cos 4 *wt*	0	0	.02%

We see from this table that including the effect of secondary distortion gives a slight increase in the percentage of second harmonic, and also shows the presence of small third and fourth harmonics.

We may conclude therefore that even when an amplifier is loaded to a point which would produce 10 per cent. 2nd harmonic without feedback applied, the application of negative feedback reduces this percentage almost exactly in the same proportion that the amplification is reduced.

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13. "The necessary conditions for Instability (or Self-Oscillation) of Electrical Circuits," D. G. Reid, *Wireless Engineer*, Nov. 1937, Vol. 14, p. 588.
14. "Regeneration in Linear Amplifiers," G. S. Brayshaw *Wireless Engineer*, Nov. 1937, Vol. 14, p. 597.
15. "Wege zur Verzerrungsminderung bei Leitungsverstärkern für Mehrfach-Nachtrichtensysteme," H. Werrmann, *Telefunken*. Vol. 18, 1937, No. 77.

WE have received a bound volume, containing a number of articles describing the work of Nikola Tesla and the speeches in many languages delivered at the gathering held at Belgrade from 26th to 31st May, 1936, in celebration of Tesla's 80th birthday. Reference is also made to a number of other commemorative speeches at various centres including Paris, Vienna, Graz, Poitiers, Prague, Sofia and Brünn, where his birthday was celebrated. The volume contains 520 pages and can be obtained from the Secretary of the Institut Nikola Tesla, rue Mirocka 4, Belgrade; price 100 French Francs.

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Abstracts and References

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For the information of new readers it is pointed out that the length of an abstract is generally no indication of the importance of the work concerned. An important paper in English, in a journal likely to be readily accessible, may be dealt with by a square-bracketed addition to the title, while a paper of similar importance in German or Russian may be given a long abstract. In addition to these factors of difficulty of language and accessibility, the nature of the work has, of course, a great influence on the useful length of its abstract.

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PROPAGATION OF WAVES

1. A New Method of Investigation of the Ionosphere [Displacement of Simple Television Images on 74 and 41.5 Metres: Some Conclusions (Regions do not move 'en bloc'): etc.].—R. Rivault. (*Rev. Gén. de l'Élec.*, 2nd Oct. 1937, Vol. 42, No. 14, pp. 435–436.)

Further development of the work dealt with in 3859 of 1936. A typical result is seen in Fig. 1, where the ground-ray image is the lower of the two, the sky-wave image being displaced vertically upwards by 5 mm and horizontally by one line towards the left. The advantages of the method over the pulse method are discussed, and results quoted. Among these, "the simultaneous use of two lengths of wave has allowed us to ascertain that the ionised regions do not displace themselves 'en bloc,' contrary to what has been indicated by English writers. The latter have even based on this assertion a method of calculating the temperatures of these regions of the upper atmosphere. Since h depends on the frequency of the wave employed, the 74 m and 41.5 m signals reflected by the F region are not so reflected at the same height simultaneously. It is habitually found that for a variation of h for the 74 m wave there is no corresponding simultaneous variation for the 41.5 m wave." For a given wave, simultaneous reflections at F and E regions have been observed. As a rule, height variations in E occur without F being affected, from which it is concluded that the ionising agents are different for the two regions.

2. The Temperature Distribution within the Auroral Region of the Atmosphere.—L. Vegard. (*Phil. Mag.*, Oct. 1937, Series 7, Vol. 24, No. 162, pp. 588–598.)

In 1923 the writer "discussed two possible ways of explaining the peculiar distribution of matter in the auroral region. The one possibility would be to assume that the temperature in the auroral region increased rapidly upwards, and the second possibility was that matter was in a highly ionised state and was driven towards higher altitudes through the effect of electric forces." He here points out the difficulties involved in the assumption of increasing temperature (as assumed by Appleton & Naismith and Martyn & Pulley, 3304 of 1935 and 3677 of 1936) and describes investigations of the auroral spectrum at Oslo and Tromsö, with results of observations of the red line 6300 and interference pictures of the green line from varying altitudes, which "give no indication of such a large increase in temperature with altitude as that maintained by" the writers mentioned. He therefore explains the "slow rate at which the density of matter decreases upwards . . . as effected by the cloud of rapidly moving electrons forming the limiting aspect of our atmosphere and by the resulting electric fields."

3. Further Studies on the Vertical Movements of the Air in the Upper Atmosphere.—L. Harang. (*Terr. Mag. & Atmos. Elec.*, March 1937, Vol. 42, No. 1, pp. 55–72.)

(i) Further evidence of diurnal temperature-variations at 100 km, from auroral height measurements. (ii) Diurnal electron-density curves during winter at high altitudes: magnitude of recombination coefficient in F_2 layer. (iii) Further observations on post-effects of magnetic storms on critical frequency of F_2 layer and on equiv. height/frequency curves. (iv) Diurnal asymmetry in development of F_1 layer. (v) Variations of reflection coefficients during magnetically disturbed periods. (vi) Occurrence of intermediate layers and reflections between layers. (vii) Annual variation of critical frequencies at noon in 1935/1936. (viii) Absence of normal E layer in midwinter.

4. The Origin of the Additional Ionisation in the "Barrier Layers" [Sperrschichten] of the Upper Atmosphere [at Heights of a Few Kilometres: Suggestion that Activity at These Heights is due to Radioactive Masses from the Stratosphere, of Extra-Terrestrial Origin].—J. Juilfs. (*Physik. Zeitschr.*, 15th Sept. 1937, Vol. 38, No. 18, p. 691.)

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5. Echo Measurements on the Ionosphere.—H. E. Paul. (*Hochf:tech. u. Elek:akus.*, Oct. 1937, Vol. 50, No. 4, pp. 121–135.)

The reflection records here described were taken in 1933/34, mostly on wavelengths of 60 and 84 m, with an apparatus (scheme Fig. 2) which allowed the separation of echoes with a height difference of 7 km and measurement to 2 km of apparent height, simultaneous recording of echoes on two different wavelengths, and echo recording at times of strong absorption (the ground wave being eliminated). The writer states that he wishes his observations to be regarded as confirmation of those already published (*e.g.*, 1933 Abstracts, p. 320); the subjects he discusses are: for F region, separation into ordinary and extraordinary components, change-over of relative position of the components (Figs. 5, 6), decrease of reflection height at the time of evening ionisation concentration, vertical movement of a change in the ionised regions with velocity about 100 m/sec., the diurnal changes in reflecting height, formation of F_1 region in the lower part of F region, change of diurnal variation with season, absorption in lower atmospheric regions, anomalous phenomena; for E region, double echoes due to double refraction or to stratification of the region; simultaneous reflection at both regions. Many records are illustrated and a list of literature references up to 1935 is given.

6. Ionospheric Disturbances, Fade-Outs, and Bright Hydrogen Solar Eruptions.—D. F. Martyn, G. H. Munro, A. J. Higgs, & S. E. Williams. (*Nature*, 9th Oct. 1937, Vol. 140, pp. 603–605.)

A typical record is shown of the effect of a bright hydrogen solar eruption on equivalent heights and echo intensities from F_2 region. From their results, the writers deduce that a type of ionospheric disturbance accompanies every bright hydrogen solar eruption. Its main features are found to be an increase of ionisation in the D region and a heating effect in and below the F_2 region. Communication "fade-outs" are caused by the large disturbances. "It is concluded that these effects are due to a greatly increased emission of the hydrogen resonance line L_α from the eruptive area. This causes ionisation of atomic oxygen in the D region, and dissociates the water vapour in the F_2 region, thus raising the equilibrium temperature." An active sunspot and bright eruptions accompanying "pronounced fadings in short-wave wireless transmission," a magnetic disturbance, and an aurora, are recorded in the same issue of *Nature*, pp. 616, 641.

7. Characteristics of the Ionosphere at Washington, D.C., January to May, 1937, *and* June, July, Aug. 1937 [including Fade-Outs].—Gilliland, Kirby, Smith, & Reymer. (*Proc. Inst. Rad. Eng.*, Sept. 1937, Vol. 25, No. 9, pp. 1174–1184: pp. 1185–1187, 1188–1191: Oct. 1937, No. 10, pp. 1354–1356.)

8. Sudden Disturbances of the Ionosphere.—Dellinger. (*Proc. Inst. Rad. Eng.*, Oct. 1937, Vol. 25, No. 10, pp. 1253–1290.) *See* 3991 of 1937.

9. Sudden Disturbances of the Ionosphere [General Remarks on High-Frequency Radio Fade-Outs, Solar Eruptions, etc.].—Dellinger. (*Journ. Franklin Inst.*, Sept. 1937, Vol. 224, No. 3, pp. 390–391.) Note on investigations dealt with in 3991 of 1937.

10. Terrestrial-Magnetic and Ionospheric Effects associated with Bright Chromospheric Eruptions [Magnetic Changes are Augmentations of Normal Diurnal Variation, produced by Increased Ionisation at Base of, or below, E Layer: etc.].—A. G. McNish. (*Terr. Mag. & Atmos. Elec.*, June 1937, Vol. 42, No. 2, pp. 109–122.) "It is suggested that normal radiation from the Sun in the extreme ultra-violet is much greater than that calculated on the assumption that the Sun is a black-body radiator at a temperature between 6000° and 7000° K." *See* also 2854 & 3986 of 1937.

11. Auroral Observations on August 1st, 1937, at Malcolm Island, Canada [during Magnetic Storm, and a Day after Radio Fade-Out and Chromospheric Eruption].—A. G. McNish. (*Terr. Mag. & Atmos. Elec.*, Sept. 1937, Vol. 42, No. 3, pp. 321–322.)

12. Results of Measurements on the Ionosphere in Various Parts of the World [Huancayo and Watheroo F_2 Electron-Density Measurements contradict Previously Accepted Hypothesis of F_2 Temperature in Relation to Latitude: Necessity for Simultaneous Measurements at Different Parts of World: Results suggest that F_2 Ionisation might be caused by Charged Particles of Relatively Large Mass].—K. Maeda & T. Tukada. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, pp. 21–29.) The measurements referred to are described by Berkner, Wells, & Seaton in *Terr. Mag. & Atmos. Elec.*, Vol. 41, 1936, p. 173. Results at different latitudes in Japan are also given.

13. Abnormal Ionisation of the E Region of the Ionosphere [Huancayo and Watheroo Observations contrasted: Sporadic Ionisation as a Function of (probably Magnetic) Latitude: No Support for Thunderstorm Theory: Relation to Magnetic Bays and Auroras ?].—Berkner & Wells. (*Terr. Mag. & Atmos. Elec.*, March 1937, Vol. 42, No. 1, pp. 73–76.)

14. Studies of Radio Fade-Outs [Continuous Data from Huancayo and Watheroo: No Recurrence or Quasi-Recurrence evident: Confirmation of Eruption Theory: Absorption of Short Waves in Region 60–100 km owing to Increase of Ionisation: No Appreciable Absorption of the Ionising Radiation in Higher Regions: etc.].—Berkner & Wells. (*Terr. Mag. & Atmos. Elec.*, June & Sept. 1937, Vol. 42, Nos. 2 & 3, pp. 183–194 & 301–309.)

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15. Solar Eruptions of November 27th, 1936, and May 25th, 1937, and Simultaneous Disturbances in Earth's Magnetism, Earth Currents, and the Ionospheric Regions [Huancayo Observations].—Davies & others. (*Terr. Mag. & Atmos. Elec.*, March & Sept. 1937, Vol. 42, Nos. 1 & 3, pp. 93 & 311.)

16. Solar Eruptions and Their Ionospheric Effects—a Classical Observation and Its New Interpretation.—J. Bartels. (*Terr. Mag. & Atmos. Elec.*, Sept. 1937, Vol. 42, No. 3, pp. 235–239.)

17. Short-Time Magnetic Fluctuations of Local Character [Irregularities accountable only on Dynamo Theory, and indicating Local Air Circulations in Ionosphere : Desirability of Simultaneous Magnetic Registrations at Points spaced about 5 Times the Ionospheric Height : etc.].—V. Vacquier. (*Terr. Mag. & Atmos. Elec.*, March 1937, Vol. 42, No. 1, pp. 17–28.)

18. The Electric Current-Systems of Magnetic Storms.—A. H. R. Goldie. (*Terr. Mag. & Atmos. Elec.*, June 1937, Vol. 42, No. 2, pp. 105–107.)

19. Cosmic Rays and Magnetic Storms.—Chapman : Störmer. (*See* 49.)

20. Study of the Ionosphere and Solar Eclipses.—V. N. Kessenich. (*Journ. of Tech. Phys.* [in Russian], No. 11, Vol. 7, 1937, pp. 1141–1152.)

A general survey of the literature on the ionosphere. The contemporary information is presented under the following headings :—(1) composition of the ionosphere ; (2) temperature of the ionosphere ; (3) ionisation and recombination ; (4) the ionosphere and the magnetic field of the earth ; (5) periodical processes of solar activity and their effect on the ionosphere ; (6) the main layers of the ionosphere ; (7) observation of the ionosphere during the solar eclipses of 1932–1936.

21. On the Result of Field-Intensity Measurements of Short Waves during the Solar Eclipse of June 19th 1936 [including Indication that Electron Density in E Region decreased by 60% during Totality].—K. Miya. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, Abstracts p. 2.)

22. A New Form of Radio Interference [Sum and Difference Frequencies between Near-By Stations].—(*See* 96.)

23. Atmospheric Cross-Modulation.—Hafekost. (*See* 97.)

24. Anomalous Dielectric Constant of Artificial Ionosphere [Theoretical Consideration of Ionospheric Dispersion Formula shows that Dielectric Constant may be greater than, equal to, or less than Unity, depending on Experimental Conditions of Discharge Tube).—S. K. Mitra & K. K. Roy. (*Nature*, 2nd Oct. 1937, Vol. 140, pp. 586–587.) An experimental curve showing the effect is quoted from 14 of 1936.

25. Theory of the Townsend Method of Measuring Electron Diffusion and Mobility, *and* Electron Temperatures and Mobilities in the Rare Gases.—W. P. Allis & H. W. Allen : H. W. Allen. (*Phys. Review*, 1st Oct. 1937, Series 2, Vol. 52, No. 7, pp. 703–707 : 707–710.)

Authors' summary of first paper :—"The Lorentz method is applied to the combined drift and diffusion of the electron stream in the Townsend experiment. The zeroth-order approximation is found to lead to the equation found by Townsend. It is shown how the next approximation is obtained. The same method is then applied to the drift of electrons in crossed electric and magnetic fields. It is found that the magnetic field changes the energy distribution as well as the direction of drift. The latter is found in close agreement with Townsend, but not with Huxley" [1287 of 1937 : for further work *see* also 1669 of 1937]. In the second paper this theory is applied to the computation of electron temperatures and drift velocities in He, Ne, and A.

26. Plasma Electron Drift in a Magnetic Field with a Velocity Distribution Function [Calculation of First-Order Correction to Distribution Function arising from Drift Motion, for Electrons with Maxwell Distribution to First Approximation : Comparison of Resulting Equations with Townsend's Earlier Results].—L. Tonks & W. P. Allis. (*Phys. Review*, 1st Oct. 1937, Series 2, Vol. 52, No. 7, pp. 710–713.) It is shown that a theorem referred to in 2864 of 1937 holds within 12 per cent.

27. The Calculation of the Time Interval between Two Successive Collisions of an Electron with Molecules in the Ionosphere [Reasoning based on This Interval being the Time between Absorption and Re-Emission of an Ionising Photon by an Electron attached to a Molecule : Numerical Results for Different Heights].—T. V. Jonescu. (*Comptes Rendus*, 4th Oct. 1937, Vol. 205, No. 14, pp. 569–571.) For previous work *see* 868 & 3283 of 1936 and 1273, 2455, & 3985 of 1937.

28. Excitation Functions of the Auroral Bands of N_2^+ and the Comet-Tail Bands of CO^+, Excited by Electron Impact [determined by Method of Photographic Intensitometry with Special Discharge Tube].—F. P. Bundy. (*Phys. Review*, 1st Oct. 1937, Series 2, Vol. 52, No. 7, pp. 698–702.)

29. New Results on the Green, Yellow, and Red Radiation emitted by the Night Sky [Observational Data from the Pic du Midi].—H. Garrigue. (*Comptes Rendus*, 13th Sept. 1937, Vol. 205, No. 11, pp. 491–493.)

30. Solar Radiation between 2000 and 3000 Å [Shortest Wavelength in This Range observable on Jungfraujoch is 2845 Å].—K. O. Kiepenheuer. (*Naturwiss.*, 8th Oct. 1937, Vol. 25, No. 41, p. 669.)

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31. The Distribution of Atmospheric Ozone in Equilibrium wtih Solar Radiation and the Rate of Maintenance of the Distribution.—Wulf & Deming. (*Terr. Mag. & Atmos. Elec.*, June 1937, Vol. 42, No. 2, pp. 195–202.) *See* also 2066 of 1937.

32. The Physical Reality of Space and Surface Waves in the Radiation Field of Radio Antennas [Separation still Possible and Useful and Not Invalidated by Sign Change in Sommerfeld Formula: the Nature of the Surface Wave—Similar to Guides Wave on Wire? etc.]—K. A. Norton. (*Proc. Inst. Rad. Eng.*, Sept. 1937, Vol. 25, No. 9, pp. 1192–1202.)

33. The Propagation of Radio Waves over the Surface of the Earth and in the Upper Atmosphere: Part II—The Propagation from Vertical, Horizontal, and Loop Antennas over a Plane Earth of Finite Conductivity ["Effective Height" as Function of Ground Constants: Influence of Aerial Height on Attenuation of High and Ultra-High Frequencies: Forward Tilt of Electric Vector: the Poynting Vector: the Fraction of Energy near Ground which flows downward into Ground: etc.].—K. A. Norton. (*Proc. Inst. Rad. Eng.*, Sept. 1937, Vol. 25, No. 9, pp. 1203–1236.)

34. The Diffractive Propagation of Radio Waves: III—The Case of "Dielectric Ground" [Extension of Previous Formulae, for Radiation from Vertical Dipole over Spherical Earth, to Ground where Displacement Current is comparable with or even greater than the Conductivity Current].—Wwedensky. (*Tech. Phys. of USSR*, No. 8, Vol 4, 1937, pp. 579–591: in English.) The paper ends with a comparison between the values derived by these formulae and the results of Jones and of Trevor & Carter on 4.9 m, 6.8 m and 8.8 m waves. For Parts I & II *see* 842 of 1937.

35. The Diffraction of Electromagnetic Waves from an Electrical Point Source round a Finitely Conducting Sphere, with Applications to Radiotelegraphy and the Theory of the Rainbow: Part II.—van der Pol & Bremmer. (*Phil. Mag.*, Nov. 1937, Series 7, Vol. 24, Supp. No. 164, pp. 826–864.)

For Part I *see* 3245 of 1937. Here "the original harmonic series for the Hertzian vector is split up into an infinite sum of other harmonic series. Each of them may be considered as the effect of waves (degenerating into rays for extremely high frequencies) which are once or more times reflected at the inner surface of the sphere. These series may be approximated by Kelvin's principle of stationary phase as extended by Debye and Brillouin; this method gives appropriate approximations for the field of a radio transmitter in the region above its optical horizon, whereas, when the point source is at infinity, it yields and extends Airy's well-known results for the intensity of light in a rainbow."

36. Contribution to the Theory of Total Reflection [Theory of Plane Wave bounded on One Side: Reflection and Refraction Formulae: Temporal Average Values of Energy in Total Reflection: Wave bounded in Space and Time].—C. Schaefer & R. Pich. (*Ann. der Physik*, Series 5, No. 3, Vol. 30, 1937, pp. 245–266.)

37. Field-Strength Observations of Trans-atlantic Signals, 40 to 45 Megacycles.—Peterson & Goddard. (*See* 218.)

38. The Propagation of Electromagnetic Waves in Water.—K. Brüne. (*Hochf: tech. u. Elek:akus.*, Sept. 1937, Vol. 50, No. 3, pp. 73–80.)

The experiments here described were made with the object of discovering to what extent ultra-short and micro-waves can be used for under-water communication, and the ranges attainable at different frequencies under various conditions. The wavelengths used were 1.3 m, 7.2 m, and 16 cm (14, 80, and 1.78 cm, respectively, in the water). Curves of measured and calculated intensities received at various distances in the water from a dipole in the water are shown for the three wavelengths in Figs. 1, 4 & 5, 6 respectively; the apparatus used in each case is shortly described. The intensity decrease is exponential. The range (distance at which the modulation sinks below the background noise) for wavelength 1.3 m was about 1 m; for 7.2 m, 23 m; for 16 cm, 12 cm. The absorption was found to decrease very rapidly with the frequency. In § IV the effect of conductivity and frequency on the magnitude of the absorption coefficient is investigated theoretically (curves Fig. 7); curve of calculated range as a function of wavelength are given in Fig. 8. The effect of a reflector of the shape of a paraboloid of rotation (Fig. 9) in the water is studied in § V. Fig. 10 shows the reflected intensity produced in water and in air; in water the subsidiary maxima are absent, owing to absorption. A similar curve is found with a plane reflector in water (Fig. 11). Use of reflectors gave no increase in range. The propagation of light and heat waves in water is generally discussed in § VI; these however are of no practical use for communication. It is concluded that only long waves (of length about 1000 m) show any promise of practical utility for under-water communication.

39. Papers on the Dispersion and Absorption of Micro-Waves [in Liquids].—Elle, Hackel, Esau, and others. (*See* 251/252.)

40. Theory of the Irradiation of Stratified Biological Objects with Ultra-Short [and Micro-] Waves.—H. E. Hollmann. (*Hochf:tech. u. Elek:akus.*, Sept. 1937, Vol. 50, No. 3, pp. 81–91.)

The phenomena occurring when a plane wave passes through a homogeneous or stratified biological object are developed on the basis of the theory of the passage of a plane wave through a material stratified in planes (§ 1). Wave absorption in biological substances (fat and muscle) is discussed in § II from tabulated values of the electromagnetic constants; Fig. 5 shows the depth of penetration as a function of wavelength.

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The passage of a plane wave through the boundary layer between two media, its reflection (Fig. 6) and reflection losses (Fig. 7), are investigated theoretically in § III and extended to several media in § IV. In order to avoid reflection losses at the surface of an object, it is suggested (§ V) that an external medium may be fitted on the surface to "match" the object, like a sort of immersion lens; "over-matching" is also discussed. § VI describes the effect of a convergent beam in penetrating a layer of fat and reaching an underlying layer of muscle, so affecting localised regions.

41. New Experimental Methods applicable to Ultra-Short Waves [Application of Wave-Guide Transmission to H. F. Electrical Measurements: Methods of Launching Various Types of Waves in Guide: Tuned Receiver based on Resonant Cavity Principle: Measurement of Dielectric Properties of Materials: Simple Hand Probe used as Wave Indicator].—G. C. Southworth. (*Journ. of Applied Physics*, Oct. 1937, Vol. 8, No. 10, pp. 660–665.)

42. Electromagnetic Waves in Conducting Tubes [Theory: Representation as Semi-Standing Waves due to Superposition of Plane Waves reflected from One Side of Tube to the Other: Certain Types transmitted without Attenuation in Tubes of Triangular, Rectangular, and Hexagonal Cross-Section].—L. Page & N. I. Adams. (*Phys. Review*, 15th Sept. 1937, Series 2, Vol. 52, No. 6, pp. 647–651.) For these waves *see* 2502/2504 of 1936 and 22 of 1937: *also* 3968/9 of 1936, and 41, above.

43. Propagation of Potential in Discharge Tubes [Speed measured as Function of Pressure and Applied Voltage in Tubes of Different Diameters: Speed obeys Principle of Similarity: Current/Time Curves: Maximum Currents in Initial Wave: Wave Fronts: Voltage Attenuation].—Snoddy, Dietrich, & Beams. (*Phys. Review*, 1st Oct. 1937, Series 2, Vol. 52, No. 7, pp. 739–746.) For previous work *see* 3246 of 1937.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY

44. Effect of Near Lightning Discharges on a Magnetometer [Magnetograms showing Sudden Kicks and Subsequent Oscillations: Theoretical Estimate of Expected Magnitudes agrees with Observation].—K. R. Ramanathan. (*Nature*, 2nd Oct. 1937, Vol. 140, p. 587.)

45. Remarks on the Paper "The Measurement of Lightning Current Values" [by Compressed Iron-Powder Bars].—Blum & Finkelnburg. (*E.T.Z.*, 28th Oct. 1937, Vol. 58, No. 43, p. 1175.) *See* 1704 of 1937.

46. The Protection of Communication Installations against Lightning by Over-voltage Protecting Gaps and Gaseous-Discharge Tubes.—Peters & Schulz. (*E.T.Z.*, 21st & 28th Oct. 1937, Vol. 58, Nos. 42 & 43, pp. 1129–1133 & 1158–1160.)

47. Lightning and Lightning Protection.—W. G. Radley. (*P.O. Elec. Eng. Journ.*, Oct. 1937, Vol. 30, Part 3, pp. 173–179.)

48. "Crystal Valve Lightning Arresters with T-Grain Crystallite."—(At Patent Office Library, London: Cat. No. 77 870: 116 pp.)

49. Cosmic Rays and Magnetic Storms [Decrease of Cosmic Ray Ionisation with Decrease of Horizontal Magnetic Force: Bearing on Mode of Origin of Magnetic Storms: Proposed Model of Earth's Field during Magnetic Storm].—S. Chapman: Störmer. (*Nature*, 4th Sept. 1937, Vol. 140, pp. 423–424.) *See* also Störmer, *Nature*, 25th Sept. 1937, Vol. 140, pp. 549–550.

50. The Measurement of Normal Atmospheric-Electric Potential-Gradients using a Valve-Electrometer.—W. A. Macky. (*Terr. Mag. & Atmos. Elec.*, March 1937, Vol. 42, No. 1, pp. 77–86.)

PROPERTIES OF CIRCUITS

51. Frequency Multiplication and Division [Requirements of Device for generating Multiple or Submultiple Frequencies controlled by a Master Frequency, as in Multiple Transmission, Suppressed Carrier Working, Television, etc: New Circuit ("Compound Generator") using Special Type of Retro-action on Valve Circuit with Non-Linear Characteristic].—H. Sterky. (*Proc. Inst. Rad. Eng.*, Sept. 1937, Vol. 25, No. 9, pp. 1153–1173.) For previous work *see* 3716 of 1936.

52. The Analytical Study of Frequency Doublers.—Taki. (*See* 88.)

53. Remarks on the Theory of the Johnson [Thermal Agitation] Effect, particularly in a Supra-Conductor: and the Proof of a Reactance Property.—H. Baerwald. (*Tech. Phys. of USSR*, No. 7, Vol. 4, 1937, pp. 556–563: in German.)

Feldtkeller (1309 of 1937) considers the Johnson noise voltage E^2 at the terminals of a resistance R_0 in parallel with a reactance which approximates, at sufficiently high frequencies, to a capacity C_0. In another paper (1714 of 1937) the same author has shown that, in the case where the reactance takes the form of a simple oscillatory circuit, calculation of the condenser voltage by the Nyquist formula "surprisingly" shows that $E^2 = kT/C_0$ and is thus independent of L_n. In the former paper the "surmise" is made that this holds good for reactances in general. The present writer shows that this follows directly from considerations of thermodynamic equilibrium.

54. The Factor of Merit ["Q Value"] of Short-Wave Coils [above 15 Mc/s, Q depends as much on Condenser as on Coil: Coil Q does Not increase appreciably with Coil Length greater than One Diameter: Winding Space Factor: Materials: etc.].—P. C. Michel. (*Gen. Elec. Review*, Oct. 1937, Vol. 40, No. 10, pp. 476–480.)

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55. Deviations in the Behaviour of Attenuation Coupling from the Known Coupling Phenomena.—G. Schmerwitz. (*Ann. der Physik*, Series 5, No. 3, Vol. 30, 1937, pp. 209–223.)

The differential equations governing the behaviour of two systems coupled by way of the damping terms are given in eqns. 1, 2 and solved theoretically (§ 2). In § 3 one of the possible solutions (formulae 5, 6, 7) is evaluated exactly for arbitrary initial conditions; the case in which the frequencies and attenuations of the two systems are equal is discussed in § 4 and the coupling factor evaluated for a special case. The theory is illustrated experimentally by the phenomena occurring when a seismometer is coupled to a galvanometer; this is the same type of coupling as that in all electrical current circuits containing two measuring instruments of galvanometer type (*e.g.* ammeter and voltmeter). The general conclusions are reached that "the new coupled frequencies are *not*, as with coupling *via* force and acceleration, further separated from one another, but tend to a common intermediate value depending on the coupling factor. When the initial frequencies are the same, they remain unchanged however strong the coupling . . . The behaviour of the attenuation constants is similar to that of the frequencies in other cases; they tend to separate, even when the initial values are the same, to a degree depending on the intensity of coupling, so that a system may become almost undamped."

56. Transient Phenomena and the Building-Up of Oscillation Amplitudes in Triode Oscillators [including Study of Band-Pass Filters].—R. Usui. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, pp. 31–56.)

Equivalent resistance of back-coupled triode oscillators, their dynamic characteristics, and the relation $1/N = F(X)$ between the reciprocal of the self-maintenance factor and the amplitude. Transient phenomena and building-up of simple triode oscillators (theory and experiment: a proposed building-up formula). Simple network forming a band-pass filter, studied by means of a fourth-order differential equation: both linear and non-linear characteristics are treated, and building-up formulae derived for each type of circuit. The work carries much further the studies dealt with in 483 of 1936.

57. Transmission Characteristics of the Band-Pass Amplifier in Superheterodyne Radio Receivers.—Hagino & Monji. (*See* 103.)

58. Theory and Application of Bridged Feedback for Fundamental Waves [including Applications of Constant-Current Circuit, Constant-Voltage Circuit, and Feedback Amplifier to Cascade Coupling Circuits and Volume Compandors].—K. Kobayashi. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, Abstracts p. 6.)

59. A Study of the Input and Output Impedance of Feedback Amplifiers [with Bridge-Circuit Feedback: Analysis and Experimental Confirmation].—K. Kobayashi. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, Abstracts pp. 6–7.)

60. On the Characteristics of the Feedback Amplifier for Fundamental Waves [Theoretical and Experimental Investigation of Frequency and Phase Characteristics, Transient Phenomena, Stability, etc.].—K. Kobayashi & Y. Dekawa. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, Abstracts p. 12.)

61. Negative Feedback [Advantages: Graphical Determination of Operating Conditions].—P. K. Turner. (*Wireless World*, 15th Oct. 1937, Vol. 41, pp. 386–387.)

62. Note on Paper by H. Pieplow:—"The Amplification of Very Wide Frequency Ranges" [Equation in Former Paper by von Ardenne is not incorrect, as Pieplow states].—M. von Ardenne. (*E.N.T.*, Aug. 1937, Vol. 14, No. 8, p. 280.) For Pieplow's paper *see* 4022, for von Ardenne's *see* 1710, both of 1937.

63. A Method for Improving the Zero-Point Stability of Multiple-Stage Push-Pull D.C. Amplifiers.—J. O. Nielsen. (*Zeitschr. f. Physik*, No. 3/4, Vol. 107, 1937, pp. 192–199.)

The circuit diagram of the amplifier in its final form is shown in Fig. 4. It is a modification of one described by Buchthal & Nielsen (Fig. 3; *Skand. Arch. f. Physiol.* 1936, Vol. 74, p. 202) in which the second stage "floats" at the anode potential of the previous stage. For application to more than two stages, as in Fig. 4, "the anode batteries of the first and third stages are coupled by a connection introduced directly between the cathode of the third stage and the equipotential point of the anode battery of the first stage. Thus the last stage and the connected output instrument are connected to earth by an alternating current through the small internal resistance of the batteries." The longitudinal stability of the circuit is shown by a theoretical investigation of a simplified circuit (Fig. 5). The effect can be explained as a negative retroaction produced by connecting the first and third stage.

64. Maximum Undistorted Output of a Triode Power Amplifier [assuming Linear Characteristics: Derivation of General Formulae, giving as Special Case the Known Law "Load Impedance = Twice Internal Resistance of Valve"].—Y. Fukuta. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, Abstracts p. 5.)

65. Harmonic Analysis of the Plate Current of a Triode Power Amplifier [with New Formulae applicable to Whole Range between Class A and Class C Operation].—Y. Fukuta. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, Abstracts p. 12.)

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66. A Graphic Representation of the Power Dissipation at the Anode of a Thermionic Rectifier.—I. S. Rabinovich. (*Izvestiya Elektroprom. Slab. Toka*, No. 7, 1937, pp. 45–47.)

The operation of a thermionic rectifier can be determined from an examination of its rectification characteristics, *i.e.* the curves $I_0 = \phi(E_0)$ where I_0 and E_0 are the rectified current and voltage respectively. In the present paper it is shown that the power dissipated at the anode of the rectifier can be represented by twice the area of a triangle formed by the rectification characteristic I_0 and the horizontal axis E_0. Separate proofs are given for the rectifiers having one of the following two types of static characteristic (*i.e.* the curve showing the relationship between the instantaneous values of the anode current I_a and the anode voltage E_a) : $I_a = SE_a$, $I_a = TE_a^2$, and $I_a = KE_a^{\frac{3}{2}}$.

It is stated that by neglecting the curvature of the rectification characteristic the error introduced into the calculation of rectifier efficiency for each of the above cases does not exceed 6%, 4%, and 6% respectively. *See* 3858 of 1937 for previous work.

67. Determination of Non-Linear Distortion from the Amplitude Characteristic or from the Curve of the Distorted Oscillation.—M. V. Laufer. (*Izvestiya Elektroprom. Slab. Toka*, No. 7, 1937, pp. 25–31.)

Methods are indicated for computing the "klirr" factor of a sinusoidal wave in which peaks are cut off either on both sides of the axis (symmetrical distortion) or on one side only (asymmetrical distortion). The two cases are examined separately and formulae are derived determining the klirr factor for each harmonic separately, up to the 9th. The total klirr factor is then calculated from these components. Graphical methods are also indicated for obtaining the necessary data for these formulae in the case when the exact variation of the amplitude is not known but an actual oscillogram is available instead.

68. Corrections to the Paper "On the Frequency and Stability of Auto-Oscillations."—Shembel. (*Izvestiya Elektroprom. Slab. Toka*, No. 7, 1937, p. 58). *See* 2493 of 1937.

69. On the Nature of the Stable Régimes of Equilibrium in a Series Connection of Iron-Cored Choke and Condenser.—E. Aretz : Rouelle. (*E.T.Z.*, 28th Oct. 1937, Vol. 58, No. 43, pp. 1160–1162.) *See* also 2119 of 1936 : *also* 918 of 1937.

70. The True Circuit Diagram [Working of a Circuit often Clearer if All Subsidiary Attributes of Components are Included].—W. T. Cocking. (*Wireless World*, 15th Oct. 1937, Vol. 41, p. 377.)

TRANSMISSION

71. On the Wavelength of the Electronic Oscillations in the Plane Magnetron [Relation between Transit Time, Anode Voltage, and Current Density].—S. J. Braude. (*Physik. Zeitschr. der Sowjetunion*, No. 1, Vol. 12, 1937, pp. 1–6 : in English.)

The writer concludes : "The above equations show that in all cases when the knowledge of the transit time is of interest, the action of the space charge must be taken into consideration. In particular this is of importance when it is necessary to construct a split-anode magnetron with high efficiency. It is known that high-efficiency split-anode magnetrons must work under such conditions that the transit time is much (5–6 times) smaller than the period of oscillation (so-called dynatron oscillations). Usually the transit time was derived from eqn. 2 [$\lambda = 10\,650/H$]. It is seen from the given calculations that this equation holds true only at very high anode potentials or very small current densities. It must be noted that the space charge can change not only the transit time of the moving electrons. It can be shown that the capacity of the magnetron can be changed by the presence of an electron space charge. Preliminary calculations showed that the dielectric constant of such a condenser (with magnetic field) can be less than unity. More details will be given in the next paper."

72. Electronic Oscillations in the Magnetron [Theoretical and Experimental Investigations].—J. J. Muller. (*Rev. Gén. de l'Élec.*, 25th Sept. & 2nd Oct. 1937, Vol. 42, Nos. 13 & 14, pp. 389–406 & 419–434.)

A full report of researches carried out at Zurich under F. Tank. For earlier papers *see* 926 of 1937. The magnetron oscillations are divided into two classes, "electronic" (wavelength inversely proportional to magnetic field) and "second-type" oscillations (including "tangential"—contrasted to the "diametral" electronic type—and "dynatron" oscillations : *see* pp. 432–433) : the writer is chiefly concerned with the "electronic" type, which have an analogy to B-K oscillations in that their period is of the same order as the electron transit time. The writer's investigation of the mechanism of these electronic oscillations shows that this analogy stretches far into the theory of this mechanism. Among other results, experiments with a three-segment magnetron (Fig. 40) show that the number and position of the gaps have no effect on the period, which depends entirely on the space charge. The efficiency of an electron oscillator depends essentially on the way in which the "favourable" electrons are eliminated. The great advantage of the magnetron is that this elimination is entrusted to a special arrangement, thus dispensing with the energy-limiting grid of the retarding-field oscillator. These "special arrangements" may be an axial electric field, supplementary (collector) electrodes, or an oblique magnetic field. The use of suitable collectors (end discs) enabled a three-phase current of 10^9 c/s to be obtained : also, the current-intensity curves as a function of the collector potential are very steep (Fig. 12), suggesting a modulation method which may be advantageous.

73. On the Theory of a Split-Anode Magnetron Oscillator [Solution indicating Two Types of Oscillation at Onset, Parallel and Push-Pull ; the Former damping out and the Latter building-up to Steady State].—S. Katsurai. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, Abstracts p. 5.)

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74. Correction to the Paper "The Electron Paths in a Magnetron under Consideration of the Space Charges" [Corrected Application of Larmor Principle to Theory of Electron Motion in Magnetron: Magnetic Field decreases Radial Component of Electric Field Strength, besides rotating Whole Electron System].—K. Kugelmann. (*Zeitschr. f. Physik*, No. 3/4, Vol. 107, 1937, pp. 283–284.) *See* Awender, Thoma, & Tombs, 1392 of 1936.

75. The Magnetron as a High-Frequency Generator [Survey of Present Status: Action of Negative-Resistance Magnetrons and of Transit-Time Magnetrons: Performance and Limitations at Ultra-High Frequencies: Multi-Segment Tubes: Bibliography].—G. R. Kilgore. (*Journ. of Applied Physics*, Oct. 1937, Vol. 8, No. 10, pp. 666–676.)

76. Production and Absorption of Electromagnetic Waves from 3 cm to 6 mm in Length [by Split-Anode Magnetron with Lecher-Wire System: Wavelength measured by Echelette Grating: Absorption by Ammonia Gas, etc.].—N. H. Williams. (*Journ. of Applied Physics*, Oct. 1937, Vol. 8, No. 10, pp. 655–659.)

77. A Grid-Controlled Magnetron with Cathode External to Anode Cylinder.—Haelbig. (*See* 131.)

78. Series Modulation of Magnetron Oscillator [including Tests on 30–200 cm Waves, Output up to 20 Watts].—H. Uchida. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, Abstracts p. 8.)

79. Modulation on the Basis of the Magnetron Principle.—B. Pavlík. (*Hochf:tech. u. Elek:akus.*, Sept. 1937, Vol. 50, No. 3, pp. 95–96.)

Fig. 1 shows a circuit in which the magnetron I behaves as a resistance varying in step with the modulation frequency, thus varying also the anode voltage of valve II and therefore the amplitude of the h.f. oscillation. Proper adjustment of the working point of I is required. Another circuit is shown in Fig. 2; a triode is excited as a h.f. emitter and placed in the axial magnetic field of two coils, of which one is adjusted to give a suitable working point while the other carries the modulation current. A short theoretical note on the action is added.

80. The Spherical Emitter [for Ultra-Short Waves].—H. E. Hollmann. (*Hochf:tech. u. Elek:akus.*, Oct. 1937, Vol. 50, No. 4 pp. 109–114.)

On the oscillator referred to in 4040 of 1937. The spherical emitter consists of two metallic hemispheres fitted with equatorial flanges and fixed on to an axial metallic tube. Fig. 1 shows a cross-section with the connections to an oscillating valve and Figs. 2, 3, photographs of various forms. Its oscillations are investigated (§ 1) with calculations of the natural frequency and tuning curves (Figs. 4–6) determined from empirical formulae. Two flat spherical segments may be used instead of hemispheres (Fig. 7) if a very short wavelength is desired without the diameter becoming too small. Valves may be built inside the sphere (§ 11, Figs. 8, 9), and thus connected directly to the optimum points of the load circuit. Valves may also be connected round the periphery of the flanges (Fig. 12). Circuit symmetry may be attained by inserting a metal plate along the equatorial plane (Fig. 10), balancing grid and anode capacities by different distances between the plate and the flanges. Symmetry is also given by two valves in a push-pull circuit (Figs. 13, 14) in which each flange is connected to the grid of one and the anode of the other valve. Fig. 15 shows a Lecher wire system coupled to the sphere.

81. On the Conductor-Core Oscillator [with Coil having (*e.g.*) Copper Core: One End of Coil connected to Plate, One End of Core to Grid: Other Ends to "B" and "C" Sources respectively: Mechanism like that of Stationary Wave Oscillator: Stability of Wavelength and Oscillation: Suitability for Ultra-Short Wavelengths], *and* On the Conductor-Core-Coil Oscillator with the So-Called B-Type Circuit.—S. Ohtaka & K. Mano. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, Abstracts p. 11: p. 11.)

82. Some Notes on Electronic Oscillation Tubes with Externally Arranged Filaments ["Six Filament Strips are arranged in Parallel, externally, as in case described by J. S. McPetrie," surrounded by Backing Electrode: Accelerating Grid and Braking Electrode in Space enclosed by Filaments: Efficiency only 1–2%].—S. Nakamura: McPetrie. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, Abstracts pp. 10–11.) For McPetrie's work *see* 991 of 1935.

83. Electronic Oscillations with Push-Pull-Type Plane-Electrode Thermionic Tubes [with Thompson-Zottu "Backing Plate": Wavelength controlled mainly by External Oscillating Circuit: only Fundamental obtained: Grid Efficiency 4%, improvable by Better Design].—S. Nakamura. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, Abstracts pp. 5–6.)

84. Frequency Stabilisation in the Ultra-Short Wave Band [Survey].—H. Awender. (*Funktech. Monatshefte*, Oct. 1937, No. 10, pp. 302–306.)

85. Some Experiments with Crystal Oscillators for Short-Wave Radio Transmitters [using High-Power Pentodes].—Koga, Miyamoto, & Morimoto. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, Abstracts p. 10.)

86. Mica Condensers of Stable Capacity.—Renne & Mukhlynin. (*Izvestiya Elektroprom. Slab. Toka*, No. 7, 1937, pp. 52–57.) The capacity of mica condensers is sometimes considerably affected by temperature variations. In this paper the exact causes of this effect are examined and practical suggestions made for increasing the thermal stability.

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87. Temperature Variation of Rotating Condensers with Air Dielectric.—Gohlke (*See* 264.)

88. The Analytical Study of Frequency Doublers used in Short-Wave Transmitters [leading to Optimum Operating Conditions: Experimental Confirmation: Elimination of Wave-Form Distortion].—I. Taki. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, Abstracts p. 6.)

89. Frequency Multiplication and Division [and the "Compound Generator" Circuit with "Reintroduction"].—Sterky. (*See* 51.)

90. Performance Characteristics of Multi-electrode Vacuum Tubes as Modulator Amplifiers [for Comparatively Narrow and Wide Ranges of Operation: Treatment based on Taylor's Expansion: Need for Special Design of Valves: Comparison of Various Modulation Systems: Superiority of Suppressor-Grid Modulation].—S. Uda & K. Numazawa. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, Abstracts p. 10.) For previous work *see* 2922 of 1937.

91. Radio-Telephony with Maximum Utilisation of the Modulation Characteristic [Automatic Contrast Compression and Expansion].—S. I. Tetelbaum. (*Izvestiya Elektroprom. Slab. Toka*, No. 7, 1937, pp. 14–21.)

The range of sound intensities of a broadcasting programme is approximately equal to 70 db (symphonic orchestra). In practice, however, owing to the requirement that the received signal should be above the noise level, the "modulation interval" of a radio transmitter, *i.e.* the range of voltages applied to it, should represent a variation in sound intensity of not more than 40–45 db. In the present paper a method is proposed for the maximum possible compression of the modulation interval, using automatic contrast compression at the transmitter and expansion at the receiver, synchronous operation being obtained by the use of an additional modulated frequency.

The operation of the system is discussed and a description is given of an experimental circuit (Fig. 3) in which sound was transmitted through two "controlled" amplifiers corresponding to the transmitter and receiver amplifier respectively, and interference introduced in the channel connecting the two amplifiers. It is stated that the operation of the circuit was very satisfactory and it is suggested that the system proposed could be used with advantage not only in radio-telephony but also in telephony over wires, sound cinema, etc.

92. On the Characteristics of a Metal-Modulator [of Carrier-Suppression Type, such as Ring Modulator] and Its Equivalent Network.—Y. Dekawa. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, Abstracts p. 8.)

93. High-Voltage Transmitter Supply Unit [900 Volts by Voltage-Doubling Circuit using Receiver-Type Rectifying Valves].—H. B. Dent. (*Wireless World*, 1st Oct. 1937, Vol. 41, p. 331.)

RECEPTION

94. Radio Receiver Problem in India [and the Indian Institute of Science Receiver based on Lines of German "People's Receiver"].—S. P. Raman. (*Electrotechnics*, Bangalore, April 1937, No. 10, pp. 92–98.)

95. The New "People's Receiver" VE 301 Wn [Improved Aerial-Tuning Arrangement and Variable Aerial Coupling: Improved Quality: etc.].—(*Funktech. Monatshefte*, Oct. 1937, No. 10, p. 324). The price is 65 RM.

96. A New Form of Radio Interference [Spurious Emissions resulting from Some Form of External Inter-Modulation between Two Stations close together (*e.g.* up to 14 km): also Interaction with Third (Distant) Station: Rectifying Effect of Imperfect Conductors not accepted as Cause: No Conclusion reached].—(*P.O. Elec. Eng. Journ.*, Oct. 1937, Vol. 30, Part 3, p. 240.) *Cf.* Hafekost, 97, below.

97. Atmospheric Cross-Modulation [Observations on Influence of Weather on "Secondary-Beat Radiations" from Brookmans Park Transmitters: Theory of Cross-Modulation in Atmosphere].—W. L. Hafekost. (*Wireless World*, 22nd Oct. 1937, Vol. 41, pp. 398–399.) For previous work see 2982 of 1936: and *cf.* 96, above.

98. Electrical Character of the Spark Discharge of Automotive Ignition Systems [Crest Currents 50–80 Amperes: Frequencies 6–10 Mc/s: Probable Presence of More Powerful Transient Phenomena too rapid for Recording, *e.g.* Natural Frequency of Discharge of Spark Plug itself would be 100–200 Mc/s, with Crest Currents 100–175 Amperes].—Peters, Blackburn, & Hannen. (*Journ. of Res. of Nat. Bur. of Stds.*, Oct. 1937, Vol. 19, No. 4, pp. 401–421.)

A cathode-ray-oscillographic investigation, using two methods—measurement of voltage across a known inductance, and deflection of the ray by the magnetic field set up by the current. Appendices deal with the derivation of an expression for the voltage across the capacitance of the oscillograph circuit, and with the displacement of the line of zero voltage on an oscillogram, due to the action of the capacitive voltage-divider.

99. The Antiparasitic Valve [for Use as Input Valve in Special Compensating Circuit with Second Aerial (connected to Cathode) running Parallel to Main Aerial to the Limit of the Interference Field (not more than about Two-Thirds of Total Height) so that Industrial Interference Potentials are balanced on Grid and Cathode to produce No Anode-Current Variation: Official Tests in Belgium].—de Monge. (*L'Onde Élec.*, Oct. 1937, Vol. 16, No. 190, pp. 578–584.)

100. Wrongly Connected Interference-Quenching Condensers [for D.C. Motors: Liability to Breakdown when Motor is Switched Off].—B. Ránky. (*E.T.Z.*, 21st Oct. 1937, Vol. 58, No. 42, p. 1146.)

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101. MEASUREMENT OF GAIN AND NOISE OF A RECEIVING SET IN FREQUENCY RANGE 20 TO 55 Mc/s [by Standard Signal Generator Method and Thermal Agitation Noise Method (1328 of 1937): Factors affecting Resonance Impedance of First Grid Tuning Circuit (Radiation Resistance, Feedback, and Surrounding Shield): etc.].—H. Seki. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, Abstracts p. 9) "Errors of noise due to the effect of feedback cannot be avoided in the standard signal generator method, but with the thermal agitation noise methods they cancel each other to some extent."

102. METHOD OF ANALYSING ACOUSTIC-FEEDBACK HOWL [Radio-Frequency, Oscillator, Intermediate-Frequency and Audio-Frequency Types].—C. O. Caulton. (*Communications* [Merger of *Rad. Engineering* and *Communication & Broadcast Engineering*], Sept. 1937, Vol. 17, No. 9, pp. 28–31.)

103. TRANSMISSION CHARACTERISTICS OF THE BAND-PASS AMPLIFIER IN SUPERHETERODYNE RADIO RECEIVERS [I.F. Circuit: Usefulness of a New Frequency Parameter χ in Analysis of Frequency Characteristics: the Use of the "Equivalent Resistance" to terminate the Filter, or (sometimes) Small Resistance in series with Inductance: etc.].—K. Hagino & M. Monji. (*Rep. of Rad. Res. in Japan*, June, 1937, Vol. 7, No. 1, Abstracts pp. 7–8.) The new parameter is $\chi = (\omega - \omega_m)/(\omega_2 - \omega_1)/2$ where ω_1, ω_2 and ω_m are the lower cut-off, higher cut-off, and geometrical mean angular frequencies respectively.

104. THE DESIGN OF INDUCTANCES FOR FREQUENCIES BETWEEN 4 AND 25 MEGACYCLES [for Radio Receivers, etc: Analysis and Experiment: Optimum Length/Diameter Ratio: Turns Formula: etc.].—D. Pollack. (*Elec. Engineering*, Sept. 1937, Vol. 56, No. 9, pp. 1169–1176.)

105. SOME PRACTICAL DATA RELATIVE TO THE COMPONENTS OF [Broadcast] RADIOELECTRIC RECEIVERS.—Adam. (*Rev. Gén. de l'Élec.*, 23rd Oct. 1937, Vol. 42, No. 17, pp. 532–540.) A companion paper to the one on valves, etc., dealt with in 2977 of 1937.

106. NEW PUSH-PULL FEED CIRCUIT [Chokes instead of Resistances in Phase-Changing Valve Circuit].—L. H. Cooper. (*Wireless World*, 22nd Oct. 1937, Vol. 41, p. 411.)

107. QUARTZ FILTERS WITH VARIABLE BAND WIDTH.—Kautter. (*Funktech. Monatshefte*, Oct. 1937, No. 10, pp. 314–318.) Based on the paper dealt with in 3284 of 1937.

108. A NEW METHOD OF AUTOMATIC SELECTIVITY [Band-Width] CONTROL.—R. Eberhardt. (*Funktech. Monatshefte*, Sept. 1937, No. 9, pp. 265–268.)

"The fundamental circuit is seen in Fig. 1. This circuit [a negative-feedback arrangement with two parallel-resonant circuits in series in the cathode lead] was originally developed for increasing the steepness of the sides of band-filter curves, and in this connection was described in the *Wireless World*, No. 18, [April] 1937. But the fact that this circuit also displays the property of automatic band-width regulation was not brought out in this article and appears to have been overlooked by the author. For only a mathematical treatment of the circuit problem, omitted in the article, allows the second property to be seen clearly."

109. METHODS FOR THE AUTOMATIC DETERMINATION OF, AND ADJUSTMENT TO, THE MAXIMA AND MINIMA CONDITIONS FOR PHYSICAL QUANTITIES [*e.g.* Automatic Tuning Correction].—W. Knopfmacher. (*E.T.Z.*, 4th Nov. 1937, Vol. 58, No. 44, p. 1200: summary only.)

110. ON THE WORKING OF TUNING-INDICATOR TUBES, PARTICULARLY THE TELEFUNKEN AM2 AND C/EM2.—K. Mie. (*Telefunken-Röhre*, Aug. 1937, No. 10, pp. 161–170.) On the tubes dealt with in 3696 of 1937.

111. NOTES ON SOME PRACTICAL COMPARISON TESTS MADE BETWEEN SEVERAL ACOUSTIC MEASUREMENT METHODS [for Broadcast Receivers: Five Different Laboratories: Possibilities of Useful Standardisation of Methods].—E. T. Dickey. (*Proc. Inst. Rad. Eng.*, Sept. 1937, Vol. 25, No. 9, pp. 1136–1152.)

112. DETERMINING THE WIDTH OF FREQUENCY BAND IN A COMMERCIAL SHORT-WAVE TELEGRAPH RECEIVER [in relation to Keying Frequency, Modulation Frequency, Oscillator Stability, Loss-Factor of Filter Coil, and Set Noise].—M. Morita & H. Seki. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, Abstracts pp. 8–9.)

113. STANDARDS ASSOCIATION OF AUSTRALIA, STANDARD RULES FOR INSTALLATION OF RADIO APPARATUS, ETC., AND STANDARD SPECIFICATION FOR SAFETY REQUIREMENTS: FORMING THE "S.A.A. RADIO CODE."—(Code No. CC.3–1937, with No. C.69–1937: Jan. 1937: 22 pp.)

114. VDE PROVISIONAL STANDARDS FOR PLUGS AND SOCKETS FOR BROADCAST RECEIVERS [Dimensioned Drawings].—(*E.T.Z.*, 7th Oct. 1937, Vol. 58, No. 40, pp. 1095–1100.)

AERIALS AND AERIAL SYSTEMS

115. THE CIRCUIT THEORY OF ANTENNAS [Advantages of "Counter-Electromotive-Force" Method over "Poynting Vector" Method: Wavelength along Aerial hitherto assumed Equal to That of Radiated Wave: Treatment avoiding This Assumption, and Application to Calculation of Current Distribution, Radiation Resistance, Shortening Factor, Action of Wave Reflector and Director: etc.].—G. Hara. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, pp. 57–73.)

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116. On the Measured Gain of Short-Wave Beam Antennas [40 Arrays, over Whole Year: Measured Gain larger than Calculated, for Lower Frequencies, but smaller, for Higher Frequencies: Gain Variation with Altitude of Sun: Gain greatly Reduced during Dellinger Effect: etc.].—M. Nakagami & K. Miya. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, Abstracts p. 1.) For a previous paper *see* 1355 of 1937.

117. On the Radiation Characteristics of Vertical Broadcast Antennas [Derivation of Simple Graphical Method of calculating Zenith Angle Characteristic, for Any Current Distribution: Conditions of Anti-Fading or High-Efficiency Aerials: etc.].—T. Kayano, K. Nakamura, & S. Sonobe. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, Abstracts p. 4.)

118. Simple Method for observing Current Amplitude and Phase Relations in Antenna Arrays [Array Adjustment greatly simplified: Field-Intensity Measurements only needed as Final Verification: Apparatus embodying Continuously Variable Calibrated Phase-Shifter].—J. F. Morrison. (*Proc. Inst. Rad. Eng.*, Oct. 1937, Vol. 25, No. 10, pp. 1310–1326.)

119. Radiation from Rhombic Antennas [Direct Theoretical Determination, including Inverted V Aerials: Stereographic Representation showing Effects of Design Variations: Methods of suppressing Subordinate Maxima: Polarisation and the (Limited) Derivation of Receiving Properties by Reciprocity Theorem].—D. Foster. (*Proc. Inst. Rad. Eng.*, Oct. 1937, Vol. 25, No. 10, pp. 1327–1353.)

120. The Series Phase Aerial Array.—N. Wells. (*Wireless World*, 15th Oct. 1937, Vol. 41, pp. 374–376.)

121. On the Tuning of Telefunken Synphase Aerials.—B. V. Braude. (*Izvestiya Elektroprom. Slab. Toka.*, No. 7, 1937, pp. 1–13.)

A theoretical investigation is presented which shows that the synphase operation of the Telefunken aerial is independent of the length of the horizontal radiators but is determined by the distance between these radiators. It is pointed out, however, that when these radiators are unduly shortened the directive properties of the aerial are adversely affected, and it is suggested that their length should be determined from considerations of the maximum permissible voltages on the feeders and the ease with which the feeders can be tuned to the travelling wave. It is also shown that the directive properties of the aerial are not appreciably affected when this is operated on a wavelength differing by $\pm 5\%$ from the fundamental. The discussion is illustrated by numerical examples.

122. Corona Effect on Long-Wave Aerials.—L. P. Kuptsova. (*Izvestiya Elektroprom. Slab. Toka*, No. 7, 1937, pp. 21–25.)

The formation of corona on power transmission lines is discussed and formulae are quoted determining the critical voltage at which losses due to corona begin to appear, and also the much higher voltage at which the corona discharge becomes visible. On the basis of this discussion it is suggested that in the case of long-wave aerials (for wavelengths of 3000 m upwards) the critical voltage will be raised if (a) the radius of the aerial conductors is increased, (b) the distance between the conductors and the earth is made as great as possible, (c) the number of similarly charged conductors is increased, and (d) the surface of the conductors is made smooth. In order to meet the last requirement it is suggested that the most dangerous portions of the conductors (near earthed objects) should be covered with aluminium tubes.

123. Earth Resistance [Measuring Method: Improvement of Effectiveness].—(*Wireless World*, 22nd Oct. 1937, Vol. 41, pp. 405–406.)

124. The "Thread-Supported" Cable ["Fadenkabel"] as the Newest Construction Form of a High-Frequency Feeder.—O. Cords. (*Hochf:tech. u. Elek:akus.*, Sept. 1937, Vol. 50, No. 3, pp. 105–107: Industry Review.)

The flexible 1 mm conductor (sturdy compared with the usual type, often as small as 0.4 mm) in the middle of the cable is kept in position by a silk thread suspension (Fig. 1) from the composite spiral "carrier" which supports it (Fig. 2). Figs. 3 & 4 illustrate the flexibility of the cable; it can be bent and tied without altering its capacity. The curves in Fig. 5 give a comparison of the attenuation of this cable with that of a concentric lead cable with paper insulation.

VALVES AND THERMIONICS

125. The Steepness of the Rectifying Characteristic [of a Diode] at Ultra-High Frequencies.—H. Döring. (*Hochf:tech. u. Elek:akus.*, Sept. 1937, Vol. 50, No. 3, pp. 91–95.)

The decrease of the steepness of a diode characteristic for ultra-high frequencies is here demonstrated theoretically, neglecting space-charge, by calculating the displacement current (§ IIa), integrating it to obtain the rectified current (§ IIb), and considering the electron paths (§ IIc), of which figures are drawn for various cases (Figs. 5–8). The increase of electron inertia with frequency can be seen from these figures. The slope decrease with decreasing λ is calculated in § IId (Fig. 11). The decrease is discussed for triodes in a retarding-field circuit (§ III) by treating them as diodes in which the path of the electrons lies between the virtual cathode and the anode. It is found that the "limiting emission angle" of the electrons is the important factor in the decrease of steepness. The theory is confirmed by measurements with special low-capacity valves (Fig. 15).

126. A Negative-Grid Triode Oscillator and Amplifier for Ultra-High Frequencies [Experimental Valves with Reduced Input/Output Interaction by Straight Double Leads from Plate and (Fin-Type) Grid: One Filament Lead Very Short].—A. L. Samuel. (*Proc. Inst. Rad. Eng.*, Oct. 1937, Vol. 25, No. 10, pp. 1243–1252.)

The larger valves have an oscillator output of

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60 w at 300 Mc/s and 40 w at 400 Mc/s; the smaller, 3 w at 1200 Mc/s and 1 w at 1700 Mc/s. A "coil-neutralised" two-stage amplifier with the larger valves gave 30% efficiency for class B operation at 144 Mc/s (60 w output).

127. Extending the Frequency Range of the Negative-Grid Tube [Illustrated Survey of Recent Progress].—A. L. Samuel. (*Journ. of Applied Physics*, Oct. 1937, Vol. 8, No. 10, pp. 677–688.)

128. Micro-Wave Retarding-Field Triode with Multi-Filament Cathode outside Grid and Retarding Electrode.—Nakamura: McPetrie. (*See* 82.)

129. Measurements of the Characteristic Constants of Some High-Frequency Pentodes at Frequencies from 1.5 to 300 Megacycles/Second.—Strutt. (*L'Onde Élec.*, Oct. 1937, Vol. 16, No. 190, pp. 553–577.) French version of the paper dealt with in 4094 of 1937.

130. Measurements on Valves and Resonant Circuits at [Ultra-High] Frequencies between 50 and 60 Megacycles/Second.—H. Lennartz & H. Koschmieder. (*Funktech. Monatshefte*, Sept. 1937, No. 9, pp. 287–292.)

Results with the methods and apparatus dealt with in 3828 of 1937. "These results are of great importance for the construction and calculation of r.f. amplifiers for ultra-high frequencies. It has been found that such problems cannot be dealt with satisfactorily by calculation, since the discrepancies between theory and practice may amount to 10–50%, as numerous published papers have shown." The measurements include comparisons of the voltage-amplification properties of resonant circuits with different coils (copper-wire solenoids and toroidal coils, with varying number of turns; copper-tube coils), and different types of valve, and comparisons of the behaviour of different valve-base materials and design (the new side-contact—pin-less—type is not appreciably better, as regards losses, than the older pin-type base: a paper by one of the writers in *Funk*, giving this result, and entitled "The Possibility of a H.F. Amplification of Ultra-Short Waves," is referred to). A special test dealt with an investigation of the decreased amplification due to the damping of the anode circuit by the action of the grid circuit of the next valve (p. 291, r-h column).

131. A Grid-Controlled Magnetic-Field Valve with a Cathode arranged outside the Anode Cylinder [to avoid Overheating from Electron Bombardment].—A. Helbig [Haelbig]. (*Hochf:tech. u. Elek:akus.*, Sept. 1937, Vol. 50, No. 3, pp. 96–98.)

See also 4046 of 1937. The cathode was arranged just outside the end of the anode cylinder (Figs. 1, 2) in order to obtain more power at wavelengths below 1 m without an excessive heating effect. Photographs of various experimental stages in the construction of the valve and of the arrangement of the cathode are given (Figs. 3–6), including a water-cooling device. It was found possible to introduce a control grid into the tube and thus to obtain direct modulation. Further possible ideas for continuing this unfinished work are described.

132. Electron-Beam Magnetron: a New Vacuum Tube for producing Very High Frequency Oscillations of Very Great Power.—Okabe. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, pp. 1–6.) The full paper, summaries of which were dealt with in 2966 & 4047 of 1937.

133. The Temperature of Electrons in a Magnetic Field.—A. Slutzkin. (*Physik. Zeitschr. der Sowjetunion*, No. 2, Vol. 12, 1937, pp. 215–232: in German.)

Author's summary:—The influence of the magnetic field on the electron temperature is determined. In the direction perpendicular to the magnetic field we find a rapid drop of the electron temperature with increasing distance from the centre of the bunched-together discharge. The temperature gradient in the direction perpendicular to the magnetic field is calculated approximately." A subsidiary result is that since, with increasing distance from the centre of the beam, both the electron temperature and the density of the plasma in which the discharge is thus concentrated decrease so rapidly, the recombination of the charges at the tube walls is also decreased; so that a plasma with much higher charge-density than otherwise can be obtained by a magnetic field.

134. The Mobility and Mean Free Path of Electrons in the Positive Column [and the Relaxation Time of the Plasma].—Gvosdover. (*Physik. Zeitschr. der Sowjetunion*, No. 2, Vol. 12, 1937, pp. 164–181: in English.)

135. Determination of the Variation of the Inverse of the Amplification Factor ["Durchgriff"] from the Discharge Function in Valves with Variable Amplification Factor [Theory].—K. Jaeckel. (*Hochf:tech. u. Elek:akus.*, Oct. 1937, Vol. 50, No. 4, pp. 135–139.)

This general theoretical solution starts from the extended space-charge formula for the cathode/anode current in a triode; eqn. 3 gives the discharge function in the form of an integral. This equation can be transformed into Abel's integral equation (§ II) which is solved in § III and applied to known examples of discharge functions. In § IV the solution is represented by power series and in § V it is evaluated for special examples (curves in Figs. 1, 2). *See* also 1934 Abstracts, pp. 324–325.

136. A Transformation for Calculating the Constants of Vacuum Tubes with Cylindrical Elements [Formulae derived by Method of Conjugate Functions for Amplification Constant, Capacitance, etc.].—W. van B. Roberts. (*Proc. Inst. Rad. Eng.*, Oct. 1937, Vol. 25, No. 10, pp. 1300–1309.)

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137. THE APPARENT INTER-ELECTRODE CAPACITANCE OF A PLANAR DIODE [Experimental Dependence on Anode-Current Value not disclosed by Previous Analyses because These ignore the Emission Velocities: New Steady-State Solution taking This into Account: Phase Angle markedly Dependent on Anode Current: Distribution of Force and Potential, etc., in Temperature-Limited Diode: Ratio of Transit Times in Space-Charge- and Temperature-Limited Diodes].—E. B. Moullin. (*Journ. I.E.E.*, Nov. 1937, Vol. 81, No. 491, pp. 667–675.)

138. THE DEPENDENCE OF THE INTER-ELECTRODE CAPACITANCES OF VALVES UPON THE OPERATING CONDITIONS [Measurements at 1 Mc/s, on Different Types of Valve, including "Acorns": Increment of Grid/Filament Capacitance with Increasing Anode Current is Not a Simple Function of Anode Current, Anode/Filament Conductance, or Mutual Conductance: probably a Function of Initial Velocity of Electrons. Reduction of Grid/Anode Capacitance with Increasing Anode Current. Insufficient Importance hitherto given to These Effects].—T. Iorwerth Jones. (*Journ. I.E.E.*, Nov. 1937, Vol. 81, No. 491, pp. 658–666.)

139. A NEW SHORT-WAVE 60 kW VACUUM TUBE [Type TW-530-B].—M. Kobayashi. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, pp. 7–15.)

140. ON THE RELATION BETWEEN GRID DRIVING POWER AND AMPLIFICATION CONSTANT OF TRANSMITTING TUBES [Theoretical Study: with Constant Ratio Amplification-Constant/Internal-Resistance, Driving Power may decrease as Amplification Constant increases, owing to Secondary Emission from Grid: Critical Value of Secondary Emission calculated].—M. Simbori. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, Abstracts pp. 4–5.) For previous work *see* 569 of 1936.

141. THE AL 5, AN OUTPUT PENTODE ON NEW DESIGN PRINCIPLES [Speech Output nearly 9 Watts, Anode Dissipation 18 Watts].—Th. Tillmann. (*Telefunken-Röhre*, Aug. 1937, No. 10, pp. 171–182.) Design, data, characteristic curves, and circuits, for the valve dealt with in 3695 of 1937.

142. ON THE WORKING OF THE AM 2 AND C/EM 2 TUNING-INDICATOR VALVES.—Mie. (*See* 110.)

143. THE ANTIPARASITIC VALVE [for Elimination of Mains- and Aerial-Borne Industrial Interference].—de Monge. (*See* 99.)

144. "LES TUBES À VIDE ET LEURS APPLICATIONS: TOME I—PRINCIPES GÉNÉRAUX" [Book Review].—Barkhausen. (*Rev. Gén. de l'Élec.*, 16th Oct. 1937, Vol. 42, No. 16, p. 482.) A French translation of the German work.

145. SPUTTERING OF THERMIONIC CATHODES IN MERCURY-VAPOUR DIODES.—N. D. Morgulis & A. M. Patiocha. (*Journ. of Tech. Phys.* [in Russian], No. 11, Vol. 7, 1937, pp. 1175–1188.) Sputtering of cathodes is investigated from the standpoint of the balance of active atoms on the surface of the cathodes. A few experiments were carried out with diodes having oxide-coated cathodes, but owing to insufficient knowledge of the processes taking place on the surface of such cathodes the greater part of the experiments were conducted with diodes using cathodes of thoriated tungsten.

The cathodes of these diodes were repeatedly reduced and made active again at various temperatures and vapour pressures, and the results so obtained were compared with the theoretical deductions. It appears that while there is a general (qualitative) agreement between the two sets of data, the experimental numerical values differ considerably from the expected results. A number of reasons are put forward to explain these divergencies.

146. THE UTILISATION OF SECONDARY EMISSION IN HIGH-FREQUENCY AND AMPLIFIER TECHNIQUE [Survey].—K. Herold. (*Funktech. Monatshefte*, Sept. 1937, No. 9, pp. 271–279.) Including the first magnetic electron-multiplier—Slepian's 1919 device (Fig. 6) for use as a high-voltage cathode.

147. PRINCIPAL LAWS OF THE EMISSION OF SECONDARY ELECTRONS FROM THE SURFACE OF METALS.—R. Warnecke. (*L'Onde Élec.*, Sept. 1937, Vol. 16, No. 189, pp. 509–540.) Already referred to in 3702 of 1937. A complementary work mentioned is that of Kollath, 2584 of 1937.

148. DISTRIBUTION OF THE SECONDARY ELECTRONS FROM ALUMINIUM NETTING.—Hagen & Sandhagen. (*See* 285.)

149. VISUAL OBSERVATIONS ON THE MALTER EFFECT [Thin Film Field Emission from Al_2O_3 films on Al].—L. R. Koller & R. P. Johnson. (*Phys. Review*, 1st Sept. 1937, Series 2, Vol. 52, No. 5, pp. 519–523.) *See* Malter, 3418 of 1936.

150. INVESTIGATION OF INCANDESCENT EMISSION BY OBSERVATIONS OF SINGLE ELECTRONS BY A PROPORTIONAL DOUBLE AMPLIFIER ARRANGEMENT [Confirmation of Richardson's Law for Single Electrons: Effect of Adsorbed Gases, Electric Fields, Surface Inequalities, on Elektron Emission].—E. H. Winkler. (*Zeitschr. f. Physik*, No. 3/4, Vol. 107, 1937, pp. 235–250.) For previous description of this apparatus *see* 4072 of 1936.

151. CONTRIBUTION TO THE THEORY OF METALS BY THE THOMAS/FERMI METHOD [with Calculations of Number of Conductivity Electrons, Work Function, etc.].—B. Mrowka & A. Recknagel. (*Physik. Zeitschr.*, 1st Oct. 1937, Vol. 38, No. 19, pp. 758–765.)

152. STUDIES IN CONTACT POTENTIALS. THE CONDENSATION OF POTASSIUM AND SODIUM ON TUNGSTEN [with Adsorption of Hydrogen on Tungsten Surfaces partly covered with Potassium], *and* THE EVAPORATION OF SODIUM FILMS.—R. C. L. Bosworth & E. K. Rideal: R. C. L. Bosworth. (*Proc. Roy. Soc.*, Series A, 1st Sept. 1937, Vol. 162, No. 908, pp. 1–31: pp. 32–49.)

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153. A Combination of the Hydrodynamic Theory of Heat Transference with the Langmuir Theory [of Energy Loss from Filaments of Different Diameters in a Gas].—W. Elenbaas. (*Physica*, Oct. 1937, Vol. 4, No. 9, pp. 761–765 : in German.)

DIRECTIONAL WIRELESS

154. An Improved Medium-Wave Adcock Direction-Finder [Balanced-Coupled System with Increased Pick-Up Factor and Small Instrumental Error : Four 8-Wire Vertical Cage Aerials with Unscreened Raised Feeders: Fine-Balance (Trimming) Condensers on Transformer Primaries : Method of Setting these Condensers].—R. H. Barfield & R. A. Fereday. (*Journ. I.E.E.*, Nov. 1937, Vol. 81, No. 491, pp. 676–681.) For the definition of "pick-up factor" *see* p. 678.

155. A Short-Wave Adcock Direction-Finder [Working Wavelength Range 35-70 Metres : 30-Ft. Vertical "Water-Pipe" Aerials with Netting-Screened Feeders : Cage-Screened Receiving Apparatus and Operator : Special Goniometer with Two Search Coils (in Parallel) mounted on Same Spindle : Calculation of Permissible Tolerance in Aerial System for Given Degree of Accuracy].—R. H. Barfield & W. Ross. (*Journ. I.E.E.*, Nov. 1937, Vol. 81, No. 491, pp. 682–690.) The latest model (footnote on p. 682) gives standard-wave error 1°–4°, pick-up factor (*see* 154, above) 4 m–10 m, and instrumental error $2\frac{1}{2}$° (maximum), and has a sense-finding device on a new principle, not described in the present paper.

156. The P.A.A. Direction Finder [of Pan-American Airways : Short-Wave Development of Adcock System, with Effective Range claimed up to 3800 Miles : Aircraft transmits Long Dash].—(*Aero Digest*, April 1937, Vol. 30, No. 40, p. 62.)

157. Improvements in Radiogoniometric Apparatus [Rocard System, specially suitable for Short and Ultra-Short Waves, depending on Equality of Reception on Two Alternated Systems of Open Aerials with Differing Diagrams].—Rocard. (French Pat. 812 807, pub. 19.5.1937 : *Rev. Gén. de l'Élec.*, 25th Sept. 1937, Vol. 42, No. 13, pp. 101–102D.) The two aerial systems may consist of a vertical aerial with a double set of reflectors, alternately switched into action : for removal of ambiguity both reflector systems can be switched out of action together so that the directive diagram is compared with an all-round diagram.

158. The Spitz Flight Recorder [Short-Wave Signals from Aeroplane are picked up by "Binaural Selector" and "Divergence Meter" (measuring Distance), and control Spot of Light on Translucent Map].—(*Inter Avia*, 20th July 1937, No. 452, p. 4.)

159. Boxing the Elements [Rooms for Testing the Effect of Wind, Rain, Snow, Arctic & Tropical Temperatures, High Altitudes, Power Dives, etc., on Aircraft Wireless Apparatus].—General Electric Company. (*Communications* (see 169), Sept. 1937, Vol. 17, No. 9, p. 40.)

160. Apparatus for Demarcating the Air-Space above an Aerodrome [for Blind Landing : by Sound Rays from Groups of Megaphones].—AEG. (*Flugsport*, 7th July 1937, Vol. 29, No. 14, Patent Sec. p. 24.)

ACOUSTICS AND AUDIO-FREQUENCIES

161. The H.F. Eddy Currents in the Cylindrical Sheath of Twisted Wire Pairs [Wide-Band Cables : the Influence of the Radius and Pitch of the Spiral, for Single Pairs and Quads screened by Non-Magnetic Concentric Sheath : etc.].—H. Buchholz. (*Arch. f. Elektrot.*, 10th Aug. 1937, Vol. 31, No. 8, pp. 507–523.) Replacing Abstract 4191 of 1937, which (as already stated in the December Index) is incorrect. *See* also 162, below.

162. Electric Curre Fields with Helical Structure [Theory].—H. Buchholz. (*E.N.T.*, Aug. 1937, Vol. 14, No. 8, pp. 264–280.)

Cf. 161, above. Author's summary :—The equations for the vector potential and for the magnetic field of a pair of uniformly twisted conductors are written down by regarding the pair as a double helix. The vector potential has none of the characteristics of a helix except its periodicity. The magnetic field, however, has the special property that its component tangential to an arbitrary cylindrical surface concentric with the pair of conductors is always perpendicular to the helix similar to the given pair through the point of observation. Fig. 3 shows the maximum value of the magnetic field-strength in the axis of the conductor pair as a function of the helical angle. Various formulae are derived for the external self-inductance of the conductor pair and reduced to a form suitable for calculation.

In the last paragraph, the eddy current is calculated which is induced in a concentric screening conductor with very thin walls by the pair of conductors carrying an alternating current. The structure of this eddy current is completely helical. A formula is given for the corresponding losses and represented by the curves of Fig. 4. These show that, with the helical angles customary in technical construction, there are in the lower frequency range no differences worthy of mention between the eddy current losses with helical and with purely axial currents.

163. Modern Systems of Multi-Channel Telephony on Cables [Bristol/Plymouth 12-Channel Carrier System and London/Birmingham (Coaxial) High-Frequency Carrier System].—A. S. Angwin & R. A. Mack. (*Journ. I.E.E.*, Nov. 1937, Vol. 81, No. 491, pp. 573–597 : Discussion pp. 597–606.)

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164. PAPERS ON COAXIAL CABLES.—Mumford : Collard : Chamney. (*See* 215.)

165. COAXIAL [and Crystal Microphones] IN THEATRE INSTALLATIONS [for Sound Reinforcement in New Theatres in England].—(*Communications* [see 169], Sept. 1937, Vol. 17, No. 9, p. 32.)

166. A UNIDIRECTIONAL MICROPHONE [Anderson's Corrugated Ribbon Microphone, One Half vibrating as Velocity Type, the Other as Pressure Type].—S. Tiruvenkatachari : L. J. Anderson. (*Electrotechnics*, Bangalore, April 1937, No. 10, pp. 85–87.)

167. THE RESISTANCE FLUCTUATION OF A SINGLE CARBON CONTACT, *and* ON THE EXCITATION THRESHOLD AND MICROPHONIC ACTION OF A SINGLE CARBON CONTACT.—N. Rjabinina. (*Journ. of Tech. Phys.* [in Russian], No. 12, Vol. 7, 1937, pp. 1256–1263 and 1264–1267.)

168. MODULATION OF ELECTROMOTIVE FORCE BY SENSITIVE FLAMES.—Z. Carrière. (*Revue d'Acoustique*, Jan./March 1937, Vol. 6, Fasc. 1/2, pp. 24–50.)

169. MIDGET REMOTE AMPLIFIER [using Acorn Valves : Frequency Response within ± 2 db from 50 to 9000 c/s : for 3 Microphone Channels].—L. C. Sigmon. (*Communications* [Merger of *Rad. Engineering* and *Communication & Broadcast Engineering*], Sept. 1937, Vol. 17, No. 9, pp. 24–25.)

170. HIGH-GAIN LOW-FREQUENCY AMPLIFIERS [for Microphones, Physiological Research, etc : Design and Operation : Special Problems involved in High Gain].—A. F. Rawdon-Smith. (*Journ. Scient. Instr.*, Oct. 1937, Vol. 14, No. 10, pp. 325–329.)

171. CONSOLE-TYPE SPEECH-INPUT EQUIPMENT [for Low-Power Broadcasting Stations and Larger Stations having Separate Control Booths for Each Studio].—J. P. Taylor. (*Communications* [Merger of *Rad. Engineering* and *Communication & Broadcast Engineering*], Sept. 1937, Vol. 17, No. 9, pp. 13–17 and 50.)

172. ACOUSTICAL EXPERIMENTS WITH TELEPHONE RECEIVERS : PARTS I & II.—F. Tyler. (*Phil. Mag.*, Oct. & Nov. 1937, Series 7, Vol. 24, No. 162 & Supp. No. 164, pp. 665–686 & 905–939.)

The velocity in free air was measured by a stationary wave method ; a rotating reflector method was also used for the velocity in pipes. An application of the pipe results to the measurement of the resonant frequency of a telephone diaphragm is described. In the discussion of the results, other forms of experimental technique are reviewed.

173. "TRANSIENT RESPONSE" : REPLIES TO CRITICISMS.—Voigt. (*Wireless World*, 15th Oct. 1937, Vol. 41, pp. 390–392.) *See* 3746 of 1937.

174. SPEECH COIL DESIGN [Improved Construction using Aluminium Former].—H. S. Haring. (*Wireless World*, 8th Oct. 1937, Vol. 41, p. 353.)

175. AN ELECTRO-ACOUSTIC TESTER FOR LOUDSPEAKERS [for Rapid Observation and Recording of Response Curves].—E. P. Fairbairn. (*G.E.C. Journal*, Nov. 1937, Vol. 8, No. 4, pp. 295–301.)

176. OSCILLATING CRYSTALS FROM ROCHELLE SALT. —Mattiat. (*See* 266.)

177. MOBILE P-A REQUIREMENTS.—A. Nadell. (*Communications* [see 169], Sept. 1937, Vol. 17, No. 9, pp. 34 and 65, 66, 68.)

178. DISC RECORDING : PRODUCTION AND THE STUDIO.—T. L. Dowey. (*Communications* [see 169], Sept. 1937, Vol. 17, No. 9, pp. 11–12 and 68, 70.) Reference is included to the work of D. P. Love and his paper "Acoustic Considerations in the Construction and Use of Sound Stages," in the *Journ. Soc. Motion Picture* Eng. ; particularly his results on the use of more than one microphone.

179. "THE 'SIMPLAT' SOUND RECORDING DISC" [Recording on Direct Play-Back Blanks, particularly the 'Simplat' Glass-Base Disc].—D. W. Aldous. (At Patent Office Library, London : Cat. No. GL-99-Z : 21 pp.)

180. ELECTRO-ACOUSTIC MUSICAL INSTRUMENTS [General Account of Methods of producing Electro-Acoustic Oscillations].—V. Aschoff. (*Naturwiss.*, 10th Sept. 1937, Vol. 25, No. 37, pp. 598–601.)

181. PIANO TOUCH [and the Iowa University Piano Camera].—C. E. Seashore. (*Scientific Monthly*, Oct. 1937, Vol. 45, No. 4, pp. 360–365.)

182. AN INVESTIGATION OF THE INFLUENCE OF INTERNAL FRICTION ON THE QUALITY OF WOOD FOR SOUNDING BOARDS.—P. Matveev & A. Rimsky-Korsakov. (*Journ. of Tech. Phys.* [in Russian], No. 12, Vol. 7, 1937, pp. 1273–1282.)

183. THE VORTEX MOTION CAUSING EDGE TONES [produced when an Air Jet strikes an Edge, for Various Jet Velocities : Dependence of Tone Frequency on Distance of Edge and Mean Velocity], *and* THE MECHANISM OF EDGE-TONE PRODUCTION.—G. B. Brown. (*Proc. Phys. Soc.*, 1st Sept. 1937, Vol. 49, Part 5, No. 275, pp. 493–507 ; pp. 508–521.)

184. MODES IN MODERN EGYPTIAN MUSIC [Their Frequency Ratios].—Mokhtar & Mosharrafa. (*Nature*, 25th Sept. 1937, Vol. 140, pp. 548–549.)

185. NEW CONTRIBUTION TO THE KNOWLEDGE OF THE STRUCTURE OF VOWELS, *and* NEW RESULTS IN THE APPLICATION OF ELECTRO-ACOUSTIC METHODS TO THE STUDY OF THE PSYCHOLOGY OF LANGUAGE.—A. Gemelli. (*Alta Frequenza*, Oct. 1937, Vol. 6, No. 10, pp. 692–695 : summaries only.)

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186. Two Simplified Techniques for Synchronised X-Ray, Sound Recording, and Cathode-Ray Oscillographic Studies of Speech.—R. Curry. (*Review Scient. Instr.*, Oct. 1937, Vol. 8, No. 10, pp. 383–385.)

187. "Sound Waves: Their Shape and Speed" [the "Phonodeik" and Its Use: Book Review].—D. C. Miller. (*Review Scient. Instr.*, Oct. 1937, Vol. 8, No. 10, pp. 370–371.)

188. Determination of Non-Linear Distortion from the Amplitude Characteristic or from the Curve of the Distorted Oscillation.—Laufer. (*See* 67.)

189. Distortion Meter [the RCA Type 69A Distortion and Noise Meter and Its Associated Equipment].—G. Swift. (*Communications* [see 169], Sept. 1937, Vol. 17, No. 9, pp. 32–33 and 50.)

190. Methods of Analysing Acoustic-Feedback Howl.—Caulton. (*See* 102.)

191. Notes on Some Practical Comparison Tests made between Several Acoustic Measurement Methods.—Dickey. (*See* 111.)

192. Transmission Measuring Sets for Audio-Frequency Testing.—General Electric Company. (*Journ. Scient. Instr.*, Oct. 1937, Vol. 14, No. 10, pp. 349–350.)

193. A Note on the Calibration of Audio-Frequency Oscillators [by Comparison with Harmonics of Standard Frequency, a Copper-Oxide Rectifier being used for the Beats: Standard may be 50 c/s Mains with Harmonic Content increased by Copper-Oxide Rectifier Bridge Circuit].—N. F. Astbury. (*Journ. Scient. Instr.*, Oct. 1937, Vol. 14, No. 10, pp. 339–341.)

194. A New Audio-Frequency Generator for Acoustic Measurements.—K. O. Lehmann. (*Zeitschr. f. tech. Phys.*, No. 10, Vol. 18, 1937, pp. 304–308.)

This apparatus (Fig. 1) is stated to have a very small "klirr" factor and a frequency continuously variable over the range of an octave, to be adjustable with good repetition of the adjustment, and to have an approximately linear scale for reading off the frequency, which is almost independent of the mains and other voltages. In principle it consists of a hollow rod-shaped spring fastened at one end; the mass at the free end is a glass tube partially filled with mercury, the height of which can be continuously varied *via* the channel in the spring. The system is set vibrating in the same way as an electro-magnetic tuning fork. The theory of the system is investigated and its construction described. The frequency spectrum (Fig. 3) shows no trace of an overtone. Fig. 5 gives the frequency calibration, Fig. 6 the voltage amplitude; Figs. 6, 7 show the voltage-independence of the frequency. The frequency constancy as regards time was also found to be very good.

195. Amplifier Gain [Western Electric Method of Calculating].—T. Blashill. (*Wireless World*, 1st Oct. 1937, Vol. 41, p. 346.)

196. The "Muffled" Room of the Compagnie Parisienne de Distribution d'Électricité [Its Construction: Use for Study of Acoustic Materials].—P. Baron. (*Revue d'Acoustique*, Jan./March 1937, Vol. 6, Fasc. 1/2, pp. 51–61.)

197. Acoustical Vibration in Buildings [Research on Transmission of Sound through Partitions].—J. E. R. Constable. (*Wireless World*, 1st Oct. 1937, Vol. 41, pp. 333–335.)

198. Acoustic Radiation Pressure and Waves of Large Amplitude.—E. Fubini-Ghiron. (*Alta Frequenza*, Oct. 1937, Vol. 6, No. 10, pp. 640–653.)

Author's summary:—The phenomena of acoustic radiation pressure are closely connected with the anomalies of the propagation of acoustic waves of large amplitude [*i.e.* not negligible compared with the wavelength]. The case of plane waves is studied, and it is found that in a fluid traversed by a progressive wave every point is subject to a variable pressure whose mean value does not coincide with the pressure when at rest. It is also found that a wall which closes the tube containing the fluid is subjected to forces which depend on the orientation of the wall and are not perpendicular to this. The result may, in a general form, be expressed by a tensor, whose terms are calculated. Only absorbent walls can be treated rigorously; all other treatments, involving reflecting walls, must be considered as approximations.

199. Noise and the Nation.—G. W. C. Kaye. (*Nature*, 4th, 11th, & 18th Sept. 1937, Vol. 140, pp. 408, 446–449, 490–491: British Association sectional presidential address.)

200. The Noise of Passenger Railway Carriages.—N. Preobragenski. (*Journ. of Tech. Phys.* [in Russian], No. 14, Vol. 7, 1937, pp. 1479–1485.)

201. The First International Acoustical Conference.—(*Nature*, 28th Aug. 1937, Vol. 140, p. 370.) Note on activities at Paris, July 1937.

202. The Power absorbed by Quartz Oscillators at Supersonic Frequencies of Different Intensities.—I. Sokolov. (*Journ. of Tech. Phys.* [in Russian], No. 13, Vol. 7, 1937, pp. 1358–1362.)

203. Circular Ultrasonic Grating in Liquids [formed within and outside Vibrating Annular Quartz Plate].—J. Cefovská. (*Nature*, 4th Sept. 1927, Vol. 140, p. 425.)

204. Optical Investigations of the Directional Characteristic of Supersonic Sources [Optical Scheme for demonstrating Supersonic Waves: Illustrations of Directional Characteristics of Quartz Crystals executing Piston-Like Oscillations].—E. Hiedemann & K. Osterhammel. (*Zeitschr. f. Physik*, No. 3/4, Vol. 107, 1937, pp. 273 282.)

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205. Some Interference Phenomena with Supersonic Waves [occurring with Superposition of Progressive and Stationary Waves and of Two Progressive Waves].—E. Schreuer & K. Osterhammel. (*Zeitschr. f. Physik*, No. 1/2, Vol. 107, 1937, pp. 44–47).

206. The Production of Chladni Figures by Means of Solid Carbon Dioxide: Part I —Bars and Other Metal Bodies.—M. D. Waller. (*Proc. Phys. Soc.*, 1st Sept. 1937, Vol. 49, Part 5, No. 275, pp. 522–530: Discussion pp. 530–531.)

207. "Der Ultraschall und seine Anwendung in Wissenschaft und Technik" [Book Review].—L. Bergmann. (*Zeitschr. V.D.I.*, 2nd Oct. 1937, Vol. 81, No. 40, p. 1176.)

PHOTOTELEGRAPHY AND TELEVISION

208. The "Tecoscope" Cathode-Ray Television Transmitter [Image focused on Semi-Transparent Caesium Cathode, Emitted Electrons focused Electrostatically on Mosaic (Silver Granules on Mica Plate) whose Image of Charges is discharged by Scanning of Electron Beam: High Sensitivity to Red and Infra-Red Light: Total Sensitivity several times greater than that of Iconoscope: Possibility of Noctovision].—Nagashima, Shinozaki, Udagawa, & Kizuka. (*Rep. of Rad. Res. of Japan*, June 1937, Vol. 7, No. 1, Abstracts pp. 12–13.)

209. The Life of Hot Cathodes in Cathode-Ray Tubes [Electro-Microscopic Investigation of Decreased Emission after Prolonged Service: due chiefly to Residual Gas, producing Destruction of Emission Centres by Ionic Bombardment].—W. Reusse. (*Funktech. Monatshefte*, Sept. 1937, No. 9, Supp. pp. 69–73.) From the German State P.O. Research Department. Ionisation manometers, capable of measuring pressures down to 10^{-6} mm Hg, assisted the tests. For a correction (diagrams accidentally interchanged) *see* October, No. 10, p. 84.

210. The Diminution of the Trapezoidal Error due to Asymmetrical Deflection in Cathode-Ray Tubes [Causes of the Error: Reduction by One U-Shaped Deflecting Plate: by Special Profile of Deflecting Plates: by Combination of Both: Philips Tube DG (and DB) 9–3].—R. Wigand, (*Funktech. Monatshefte*, Oct. 1937, No. 10. Supp. pp. 80–81.)

211. Investigations on the H.F. Resistance of Thin-Film Resistances [Criticism of Methods of Boella and of Puckle: a New Technique for High and Ultra-High Frequencies, and Its Results: Frequency Characteristic influenced not only by Capacitive Effects but also by Film Inhomogeneity and by Losses in Carrier Material: Equivalence to Parallel Connection of a Frequency-Independent and a Frequency-Dependent Resistance].—H. Strack. (*Funktech. Monatshefte*, Oct. 1937, No. 10, pp. 307–314.) For the work of Boella and of Puckle *see* 3225 & 3226 of 1935.

212. Photo-Conductivity and Phosphorescence of Zinc-Blende [Linear Resistance/Time Relation for Quenching of Crystal Conductivity by Infra-Red Light: Agreement with Phosphorescence Decay Data].—A. L. Reimann. (*Nature*, 18th Sept. 1937, Vol. 140, pp. 501–502.)

213. Method of Measuring the Line Lag [Group Transit Time] in Wide-Band Transmission Systems [Cables for Television].—F. Ring. (*Funktech. Monatshefte*, Sept. 1937, No. 9, Supp. pp. 73–74.)

From the German State P.O. Research Department. Of the three necessary properties of a wide-band system for high quality (*e.g.* a television cable), two—an over-all transmission loss constant over the whole frequency range, and a small non-linear distortion—can be measured easily; but the third, the constancy of the line lag (impedance angle rising linearly with frequency), is difficult to measure, particularly for long television cables with comparatively long line lags. By the method here described, however, line-lag differences of one-tenth of a microsecond in lags of the order of 2000 μsec. (600 km loop of cable) can be measured; this accuracy is suitable for the new standard television, where the duration of a picture element is only about $\frac{1}{2}$ μsec. and the line-lag constancy must be of the same order.

The two pairs of deflecting plates of a cathode-ray oscillograph are connected to the beginning and end of the cable loop: at the beginning there is also a signal generator. If the starting and returning frequencies are in phase, the screen shows a slanting straight line, which resolves itself into an ellipse if the two frequencies become out of phase. If the signal frequency is increased by a small amount ΔF, the returning frequency will lag in phase by an angle $\Delta\alpha$. With long cables, with their large line lags, quite a small frequency change causes a large phase rotation: thus with a 600 km cable a change of 50 kc/s produces more than 100 full rotations of 360°. The quantity required to be measured is line lag $T = \Delta\alpha/\Delta\omega = n/\Delta F$, where n is the number of full rotations. On a screen of 100 mm diameter, with a sharply defined spot, $\Delta\alpha$ can easily be measured to within 3.6° (a suitable accuracy which, without great difficulty, can be increased still further) by noting the lengths of the major and minor axes of the ellipse. The measurement of $\Delta\omega$ can be made with an ordinary wavemeter in the case of small line lags; for long lags the accuracy of measurement must be increased, the most suitable way being a frequency-spectrum method in which a stabilised carrier is modulated by a short impulse giving a sideband, on each side of the carrier, of frequencies all differing by the same amount, the impulse frequency (*e.g.* 50 kc/s). The interference notes between the test frequency and suitable frequencies from this spectrum are measured by an a.f. bridge.

The paper ends with a discussion of the case where the two ends of the cable are not available at the measuring point.

214. The H.F. Eddy Currents in the Cylindrical Sheath of Twisted Wire Pairs [Wide-Band Cables], *and* Electric Current Fields with Helical Structure.—Buchholz. (*See* 161/162.)

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215. The London/Birmingham Coaxial Cable System: Part I; *also* London's Television Twin Cable Links; *and* Anglo-Dutch Coaxial Cables.—A. H. Mumford: J. Collard: R. M. Chamney. (*P.O. Elec. Eng. Journ.*, Oct. 1937, Vol. 30, Part 3, pp. 206–214: pp. 215–221: pp. 222–224.)

216. The Television Cable used in the Coronation Broadcast from Alexandra Palace. —(*Elec. Review*, No. 120, 1937, pp. 889–890.)

217. Field-Strength Measurements on Ultra-Short Wavelengths [Measurements of Contours for Alexandra Palace Transmissions].—B.B.C. (*Journ. Television Soc.*, June 1937, Vol. 2, Part 8, pp. 274–277.) From the *B.B.C. Annual*, 1937.

218. Field-Strength Observations of Trans-atlantic Signals, 40 to 45 Megacycles [from Alexandra Palace Television Station: Comparison with F_2 Layer Heights: Average Height (deduced from Arrival Angles of London Transmissions and U.S.A. Amateur 29 Mc/s Band Transmissions) about 340 km, compared with Bureau of Standards' 240 km Minimum Height].—H. O. Peterson & D. R. Goddard. (*Proc. Inst. Rad. Eng.*, Oct., 1937, Vol. 25, No. 10, pp. 1291–1209.) Berlin transmissions were also received, but are not plotted.

219. A New Method of Investigation of the Ionosphere [by Television Images].—Rivault. (*See* 1.)

220. "Television Engineering" [Book Review]. —J. C. Wilson. (*Wireless Eng.*, Dec. 1937, Vol. 14, No. 171, p. 656.)

221. The "Mean Tint" [Teinte moyenne] in Television [or "Mean Transparency" in Teleciné Working: the Question of the Necessity for the Transmission of the D.C. Component: an Octode Receiving Circuit]. —R. Barthélémy. (*L'Onde Élec.*, Sept. 1937, Vol. 16, No. 189, pp. 497–508.)

222. Radiolympia, 1937 [Television Exhibits].— (*Journ. Television Soc.*, June 1937, Vol. 2, Part 8, pp. 280–284.)

223. The Great Television Special Exhibit in the "Deutsche Museum" (Munich).— J. R. Lenz. (*Funktech. Monatshefte*, Oct. 1937, No. 10, Supp. pp. 77–80.)

224. Large Screen Television.—(*Wireless World*, 15th Oct. 1937, Vol. 41, pp. 380–381.)

225. Television for the Deaf—an Experiment [at Erith Home for Deaf and Dumb Men].— (*Journ. Television Soc.*, June 1937, Vol. 2 Part 8, p. 273.)

226. Stereoscopic Cinematography by means of Coloured Anaglyphs.—Ginsburg & Levington. (*Journ. of Tech. Phys.* [in Russian], No. 13, Vol. 7, 1937, pp. 1346–1357.)

227. Orthostereoscopy [Correct "Depth" Relations and Undistorted Perspective in Stereoscopic Views require Rigorous Relations between the Parts of the Apparatus]. —H. F. Kurtz. (*Journ. Opt. Soc. Am.*, Oct. 1937, Vol. 27, No. 10, pp. 323–339.)

228. Frequency Multiplication and Division [and the "Compound Generator" Circuit with "Reintroduction"] *and* The Analytical Study of Frequency Doublers.— Sterky: Taki. (*See* 51/52.)

229. Frequency Response in Television Amplifiers [and the Special Wave-Forms of Television Signals].—W. T. Cocking. (*Wireless World*, 8th Oct. 1937, Vol. 41, pp. 354–356.)

230. Note on Paper by H. Pieplow:—"The Amplification of Very Wide Frequency Ranges."—von Ardenne. (*See* 62.)

231. The Utilisation of Secondary Emission in High-Frequency and Amplifier Technique.—Herold. (*See* 146.)

232. Electron Multipliers [Baird Multiplier Photocell].—N. W. Maybank: Baird. (*Wireless World*, 8th Oct. 1937, Vol. 41, pp. 350–352.)

233. Water Vapour in the Construction of More Sensitive Photoelectric Cells of Alkali Metals.—J. Kunz, J. T. Tykociner, & L. P. Garner. (*Journ. Opt. Soc. Am.*, Oct. 1937, Vol. 27, No. 10, p. 354.) A note pointing out that this application of water vapour, dealt with in an abstract published by Kunz (*see* 3071 of 1937), is the outcome of cooperative research by the three writers.

234. Effect of Temperature on Photoelectric Emission [Theory].—R. J. Cashman. (*Phys. Review*, 1st Sept. 1937, Series 2, Vol. 52, No. 5, pp. 512–518.)

"A survey of the existing theories of photoelectric emission near the threshold shows that . . . for $\nu = \nu_0$, $I = \text{const.} \times T^n$. Different theories demand values of n from $\frac{1}{2}$ to 5/2 . . . An analysis of the existing photoelectric data shows that n lies between about 0.7 and 1.7 for the different elements. The apparent departure from a T^2 law can be adequately explained if it is assumed that the work function increases with temperature . . . A new method for determining temperature coefficients is suggested which depends on data taken at the threshold. These values predict an intersection of spectral sensitivity curves for different temperatures in agreement with experiment. This suggests an alternative method for determining temperature coefficients using data at the point of intersection . . . The value of the constant A in Richardson's thermionic equation is computed" with the assumption of a temperature coefficient of the work function; the values agree with those determined experimentally.

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235. NORMAL ENERGY DISTRIBUTION OF PHOTOELECTRONS FROM THIN POTASSIUM FILMS AS A FUNCTION OF TEMPERATURE [studied with Retarding Potential between Plane Parallel Electrodes: Current/Voltage Curves Parabolic in Shape up to Point of Zero Field: Results compared with Various Theories: Agreement with DuBridge's Distribution (1933): Temperature Effects].—C. L. Henshaw. (*Phys. Review*, 15th Oct. 1937, Series 2, Vol. 52, No. 8, pp. 854–865.)

236. THE ANGULAR DISTRIBUTION OF PHOTOELECTRONS FROM THE *K* SHELL.—F. F. H. Eggleston & L. H. Martin. (*Proc. Roy. Soc*, Series A, 1st Sept. 1937, Vol. 162, No. 908, pp. 95–110.)

237. CONTRIBUTION TO THE THEORY OF METALS BY THE THOMAS/FERMI METHOD [with Calculations of Number of Conductivity Electrons, Work Function, etc.]—B. Mrowka & A. Recknagel. (*Physik. Zeitschr.*, 1st Oct. 1937, Vol. 38, No. 19, pp. 758–765.)

238. ELECTRICAL AND OPTICAL BEHAVIOUR OF SEMICONDUCTORS: XII—THE INTERNAL PHOTOELECTRIC EFFECT IN CRYSTALLINE CUPROUS OXIDE [Measurements with Cuprous Oxide Plates in an Electrolytic Solution].—G. Faltz. (*Ann. der Physik*, Series 5, No. 2, Vol. 30, 1937, pp. 193–208.)

239. X-RAY STUDIES OF GLASSY [Amorphous] SELENIUM AND OF ITS CRYSTALLISATION.—J. A. Prins & W. Dekeyser. (*Physica*, Oct. 1937, Vol. 4, No. 9, pp. 900–908: in French.)

240. BECQUEREL EFFECT WITH LEAD SULPHIDE [Illumination with Alternating Light gives Photoelectric Currents in Electrolyte without External E.M.Fs.].—F. Fischer, B. Gudden, & M. Treu. (*Zeitschr. f. Physik*, No. 3/4, Vol. 107, 1937, pp. 200–204.)

241. NEW INVESTIGATIONS ON THE EFFECT OF LIGHT ON THIN METALLIC FILMS.—Q. Majorana. (*Physik. Zeitschr.*, 1st Sept. 1937, Vol. 38, No. 17, pp. 663–667.)

See also 3076 of 1937. Glass plates covered with gold foil or a cathode-sprayed gold film were used, with cuts in the metal which brought the resistance always to about 15 ohms (Fig. 2). The effect is studied as the phase displacement ϕ between the periodic illumination of the film and the periodic current change due thereto. The behaviour of the foils stuck on to the glass was very irregular but showed the phenomenon (also found with cathode-sprayed films) that ϕ was smaller when a mercury-quartz lamp was used than with the incandescent lamp. This is inexplicable on a purely thermal theory. The experimental results for cathode-sprayed films are shown in Fig. 3, with the curve obtained on a thermal theory. This theory is discussed and found to explain many phenomena, but not all, and the writer finds himself driven to assume a new kind of action of light by absorption on metal surfaces, though he cannot yet make any hypothesis as to its nature.

242. COUNTERS FOR THE VISIBLE SPECTRUM [in which Bombardment of Cathode by Ions is avoided by Separating Photocathode from Discharge Chamber Proper by Foil Transparent to Electrons: Each Photoelectron passes through Foil and causes Discharge: Method of Preparing Suitable Glass Foils].—K. O. Kiepenheuer. (*Zeitschr. f. Physik*, No. 3/4, Vol. 107, 1937, pp. 145–152.)

243. INVESTIGATIONS OF THE KERR EFFECT OF SOME NITRO-COMPOUNDS [Measurement of Kerr Constant, Conductivity, Resistance to Breakdown of Nitrobenzol and *m*- & *o*-Nitrotoluol: Method of Purification: Apparatus].—F. Gabler & P. Sokob. (*Zeitschr. f. tech. Phys.*, No. 10, Vol. 18, 1937, pp. 322–326.)

244. THE DEPENDENCE OF THE KERR ELECTRO-OPTIC EFFECT ON TEMPERATURE, FOR CARBON DISULPHIDE AND HALOWAX OIL.—Zuehlke & Ingsersoll. (*Journ. Opt. Soc. Am.*, Sept. 1937, Vol. 27, No. 9, pp. 314–317.)

MEASUREMENTS AND STANDARDS

245. ATTENUATION MEASUREMENTS WITH METRE WAVES.—L. Rohde & H. Schwarz. (*Hochf: tech. u. Elek:akus.*, Sept. 1937, Vol. 50, No. 3, pp. 98–102.)

Two instruments for measuring attenuation of oscillating circuits for metre waves are described. §1 gives a new indirect substitution method (scheme Fig. 1), in which an electron valve is used to produce a variable high resistance to be put in parallel with the circuit under investigation and varied until the resonance voltage falls to half its value, the induced voltage being kept constant. § II described the use of the half-value method. The necessary detuning takes place in the generator. Fig. 3 shows the scheme of the circuit with mains connection. Tabulated results of measurements on resonance circuits, valves, "litz" wire, condensers and high resistances are given. The effective working impedances of the high resistances (Table 4) was found to decrease markedly with increasing frequency; the more so, the higher the nominal resistance. An explanation of this is given.

246. NEW EXPERIMENTAL METHODS [connected with Wave-Guide Technique] APPLICABLE TO ULTRA-SHORT WAVES.—Southworth. (*See* 41.)

247. MEASUREMENT OF GAIN AND NOISE OF A RECEIVING SET IN FREQUENCY RANGE 20 TO 55 Mc/s.—Seki. (*See* 101.)

248. THE CALIBRATION OF CURRENT-MEASURING INSTRUMENTS IN THE FREQUENCY RANGE 3×10^6 TO 3.75×10^7 C/S BY MEANS OF A PYROMETER.—H. Hoyer. (*Physik. Zeitschr.*, 15th Aug. 1937, Vol. 38, No. 16, pp. 602–609.)

A single-filament tungsten lamp (Fig. 1) in conjunction with a pyrometer (Fig. 2) is used to test current-measuring instruments in the given frequency range. Every current measurement is controlled by a substitution measurement with direct current. Investigations are described of the best way of constructing the circuit in order to avoid h.f. disturbances (Figs. 3, 5, 6). "The emitter is placed in a double screen cage; the

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symmetrical measuring circuit is coupled to the emitter inside the cage while the measuring instruments are outside it." The circuit (Fig. 5) is arranged so that the current measuring instruments are at voltage nodes. A description is given of a test of a precision thermal instrument.

249. MEASUREMENTS ON VALVES AND RESONANT CIRCUITS AT ULTRA-HIGH FREQUENCIES BETWEEN 50 AND 60 MEGACYCLES/SECOND.—Lennartz & Koschmieder. (*See* 130.)

250. THE THEORY OF THE DRUDE-COOLIDGE [Lecher-Wire] METHOD FOR THE CASE OF THE MEASUREMENT OF LARGE LOSS ANGLES.—N. N. Malov. (*Physik. Zeitschr. der Sowjetunion*, No. 1, Vol. 12, 1937, pp. 111–117 : in German.)

"With large loss angles the Morton formula [which gives good results for small angles] is incorrect, since the active [parallel] resistance of the condenser must be taken into account : the final formula [$\tan\delta = 1/\omega RC$, found satisfactory for very small loss angles] is also changed in this case. If the sample is included in a plate condenser, the condenser resistance R must be considered even for a loss angle $\delta = 13°$–$15°$, corresponding, for a wavelength of 400 cm and a dielectric constant $\epsilon = 80$ (aqueous solutions), to a conductivity around 7×10^{-4}/ohm.cm. Calculation, as well as preliminary measurements, have shown that with a suitable condenser (small plate area, large gap) connected at a suitable point in the system, conductivities around 2–3×10^{-3}/ohm.cm. can be measured, the damping of the system being not yet too great. It is therefore of interest to develop the theory of the Drude-Coolidge method for the case of large loss angles."

251. THE ABSORPTION OF CENTIMETRE WAVES IN LIQUIDS AND SOLUTIONS [Measurements at 4 cm Wavelength with Hertzian Oscillator and Bolometer : Measurements on Glass, Organic Liquids, Chloride Solutions : Possibility of Separation of Dipole Losses from Those due to Ionic Conductivity of Electrolyte].—D. Elle. (*Ann. der Physik*, Series 5, No. 4, Vol. 30, 1937, pp. 354–370.)

252. DISPERSION AND ABSORPTION WITH ULTRA-SHORT WAVES : (a) DIOXANE/WATER MIXTURES AS COMPARISON LIQUIDS AT HIGH FREQUENCIES : (b) DISPERSION AND ABSORPTION OF WATER IN THE INFRA-RED AND DEBYE'S DIPOLE THEORY : (c) REFLECTION AND ABSORPTION MEASUREMENTS WITH WATER AND ALCOHOLS FOR CENTIMETRE WAVES.—W. Hackel & M. Wien : G. Hettner : A. Esau & G. Bäz. (*Physik. Zeitschr.*, 1st Oct. 1937, Vol. 38, No. 19, pp. 767–770 : 771–774 : 774–775.)

253. ELECTRICAL SATURATION IN DILUTE SOLUTIONS OF NITROBENZOL [Measurements : Validity of Debye's Theory].—A. Piekara. (*Physik. Zeitschr.*, 1st Sept. 1937, Vol. 38, No. 17, pp. 671–674.) *See* also 1896 & 2726 of 1937.

254. DIPOLE LOSSES AND MOLECULAR STRUCTURE [Results for Alcohols : Rotation of OH-Group responsible for Losses and Dispersion].—E. Keutner & G. Potapenko. (*Physik. Zeitschr.*, 15th Aug. 1937, Vol. 38, No. 16, pp. 635–636.) *See* also d'Or & Henrion, 3427 of 1937.

255. "ALTERNATING CURRENT MEASUREMENTS AT AUDIO AND RADIO FREQUENCIES" [Book Review].—D. Owen. (*Wireless Eng.*, Oct. 1937, Vol. 14, No. 169, p. 536.)

256. FREQUENCY-MODULATED TEST OSCILLATORS [for Receiver Alignment, using Miniature Cathode-Ray Tubes : Survey of Recent Systems].—W. G. Hayman. (*Electrotechnics*, Bangalore, April 1937, No. 10, pp. 76–81.)

Various ways of producing the modulation are discussed, including DuMont's "frequency wobbler" (one plate of condenser is of steel and is vibrated by mains-energised solenoid), motor-driven capacity (RCA and Clough-Brengle) and inductance (rotating copper disc) modulators, and electronic methods (the method based on the Miller effect is particularly recommended). The Triumph "Wobbulator" circuit using a gas triode is also given.

257. ALL-WAVE OSCILLATOR [100 kc/s–30 Mc/s : with Provision for 400 c/s Internal Modulation, or External Modulation].—(*Journ. Scient. Instr.*, Oct. 1937, Vol. 14, No. 10, pp. 353–354.)

258. A BRIDGE BALANCE INDICATOR [Breazeale's Use of 6E5 Visual-Indicator Tube made suitable for Low Voltages and High Precision].—R. L. Garman : Breazeale. (*Review Scient. Instr.*, Sept. 1937, Vol. 8, No. 9, pp. 327–329.) For Breazeale's paper *see* 3129 of 1936.

259. THE WHEATSTONE BRIDGE FOR RADIO FREQUENCIES.—V. Balasubramanyam. (*Electrotechnics*, Bangalore, April 1937, No. 10, pp. 82–84.)

260. WHEATSTONE BRIDGE AND ELECTROLYTIC RESISTOR FOR IMPEDANCE MEASUREMENTS OVER A WIDE FREQUENCY RANGE [30 c/s to 10 Mc/s].—K. S. Cole & H. J. Curtis. (*Review Scient. Instr.*, Sept. 1937, Vol. 8, No. 9, pp. 333–339.)

261. METHOD OF MEASURING THE LINE LAG IN WIDE-BAND TRANSMISSION SYSTEMS.—Ring. (*See* 213.)

262. A HIGHLY SENSITIVE AND INERTIA-FREE FREQUENCY METER ["Sudden Phase Shift" Principle : Full Scale covers $\pm$ 0.9 ‰ of Rated Frequency : for 500 or 50 c/s].—W. Lutz. (*E.T.Z.*, 23rd Sept. 1937, Vol. 58, No. 38, pp. 1036–1037.)

263. INTERCOMPARISON OF FREQUENCY STANDARDS BY MEANS OF MODULATION EMISSION—EIGHTH REPORT OF THE SUB-COMMITTEE FOR FREQUENCY STANDARDS [Values of Modulation Frequency measured by 4 Japanese Laboratories agreed within Max. Difference of 3 Parts in 10 Million].—Mitsuda, Tani, & Kusunose. (*Rep. of Rad. Res. in Japan*, June 1937, Vol. 7, No. 1, pp. 17–20.)

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264. Temperature Variation of Rotating Condensers with Air Dielectric.—W. Gohlke. (*E.N.T.*, Aug. 1937, Vol. 14, No. 8, pp. 258–264.)

For a similar investigation *see* Thomas, 4013 of 1936. The h.f. beat method is here used; the change in condenser capacity is measured by the frequency change in the beat note (Fig. 1). Errors arising through undesired frequency changes in either of the oscillators are avoided by regulating the frequency of the oscillator containing the condenser under investigation by switching in an additional condenser and adjusting the inductance to make the beat frequency exactly 400 c/s before each measurement. Various precautions in the construction of the apparatus are shortly described; the results of investigations on four different makes of condenser are given (Tables 1, 2; Figs. 3–8). The chief cause of capacity change is found to be surface expansion of the plates and linear expansion of the distance between them. The temperature variation of the dielectric causes about one-tenth as much variation as the expansion. Careful mechanical construction of the condenser also tends to decrease the temperature variation. The special variation in the initial capacity of one of the condensers is traced to the different temperature coefficients of the materials used for the fixed plates and for the rotating plates respectively (Fig. 9). The behaviour of another condenser (Figs. 8, 10) is also explained theoretically. The effect of the condenser screen is mentioned.

265. Piezoelectric Crystal with Low Natural Longitudinal Frequencies, particularly for Audio-Frequency [Circular Ring with Piece cut out].—G. Gruetzmacher. (*Hochf:tech. u. Elek:akus.*, Oct. 1937, Vol. 50, No. 4, p. 143: German Patent 646 298 of 7.12.1935.)

266. Oscillating Crystals from Rochelle Salt.—O. Mattiat. (*Hochf:tech. u. Elek:akus.*, Oct. 1937, Vol. 50, No. 4, pp. 115–120.)

The growth of crystals from solution is described (Fig. 1); bars of a few centimetres' length cut in definite orientations relative to the crystal axes were used for the experiments. Fig. 2 shows the moduli of elasticity in the principal planes and Fig. 3 a model of them in space. There is an optimum direction for oscillation in which the oscillations are purely longitudinal. Data of 30 crystal bars are given in Table 10. The variation of the natural frequency of a crystal with its breadth/length ratio is shown in Fig. 4b; Fig. 6 gives the variation with the angle of inclination of the geometrical axes of the crystal to the crystallographic axes, Fig. 7 the temperature variation of the natural frequency, which is much higher than for quartz. The equivalent circuit (Fig. 8) of the crystal is discussed and the resonance curves (Fig. 11) measured with the circuit of Fig. 10. The relative frequency distance between the points of series and parallel resonance is given in eqns. 12, 13 (data in Table 2).

Oscillating circuits constructed with the crystals are found to possess small attenuation as compared with those including coils, but much greater than those containing quartz. The attenuation was measured by a substitution method (Fig. 10). In Table 3 the equivalent circuit elements and attenuation of various crystals are given and compared with those for a quartz crystal. An appendix gives a calculation of the elasticity modulus of Rochelle salt for any orientation of the crystal axes.

267. Circuits for Oscillographic Frequency Comparison [avoiding Limitation of Kurrelmeyer's Circuit (2774 of 1936)], *and* Note on the Preceding Paper.—H. J. Reich: B. Kurrelmeyer. (*Review Scient. Instr.*, Sept. 1937, Vol. 8, No. 9, pp. 348–349: p. 349.)

A footnote added at the last moment mentions that Rangachari's paper in *Experimental Wireless*, 1928, entitled "The Harmonic Comparison of Radio-Frequencies by the Cathode-Ray Oscillograph," describes a similar circuit but was previously missed by the author because it was not listed in the *E.W. & W.E.* index, or in the "Abstracts & References," under either "Frequency" or "Oscillograph." The facts are as follows: in the General Index, which is merely an alphabetical list of titles, in no way classified, the paper appears under "H" for the first significant word in the title, "Harmonic." In the "Abstracts & References" it was dealt with in the Section to which, being essentially concerned with measuring technique, it definitely belongs: namely "Measurements & Standards" (p. 346). Accordingly, in the Index to "Abstracts & References" it appears in this Section, with the key word "Oscillograph." The failure to find it was thus evidently due to the use of the *right* key word but the *wrong* Section—probably "Subsidiary Apparatus & Materials," where oscillographs in general are usually treated.

268. A Logarithmic Modulating Valve Voltmeter for Small H.F. Voltages.—W. Kautter. (*E.N.T.*, Aug. 1937, Vol. 14, No. 8, pp. 253–257.)

This self-modulated valve voltmeter (circuit Fig. 2) is designed for the frequency range 40–2500 kc/s. It consists of "two electrically separate parts, the h.f. section with the modulation and the a.f. section with the resonance amplifier," each carefully screened and fed separately from the mains. "The incoming unmodulated h.f. voltage is amplified aperiodically in an h.f. pentode . . . and passed to the grid of a hexode [AH_1, Fig. 2] where the h.f. is modulated with an audio-frequency of 1 kc/s from a fixed, screened oscillator stage. In the anode circuit of the hexode there is now, in addition to the modulated h.f., the audio-frequency, which is eliminated by a two-stage condenser circuit. This forms the only connection with the a.f. section, where the modulated h.f. is rectified by a diode, so that again an a.f. of 1 kc/s is obtained. . . . This is amplified and rectified through a valve ABC_1 . . . part of the resulting d.c. voltage controls the anode current of ABC_1 from its quiescent value down to zero, while the larger part acts as the bias on the grids of the two hexodes, so that their amplification falls as the input rises. This is how the large range of the instrument is obtained. The anode current of the final valve decreases with increasing input. The range is practically logarithmic from 100 μv to 140 mv (calibration curve Fig. 3). The frequency

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curve is given in Fig. 4. Reference is made to the use of the instrument for measurements of impedance, capacitative coupling, transformation ratio of h.f. transformers, testing and adjustment of instruments, and coil attenuations. "The instrument is suitable for working a 10 mA current recorder. It is constructed so that neither the recorder nor the built-in measuring instrument can be injured by voltage impulses of any origin whatever."

269. THE DESIGN, CONSTRUCTION, AND TESTING OF AN APERIODIC H.F. AMPLIFIER FOR VALVE VOLTMETERS FOR FREQUENCIES UP TO 10 Mc/s [Choke Coupling].—H. Peschke. (*Funktech. Monatshefte*, Oct. 1937, No. 10, pp. 297–302.)

270. A [Dynatron] DAMPING METER AS A COMMERCIAL MEASURING INSTRUMENT [Mains Driven, with Stabilovolt and Barretter Stabilisation: for Decrement, Resistance, and Inductance Measurements, Determination of Self-Capacity of Coils, and Wavelength Measurement].—A. Peetz. (*Funktech. Monatshefte*, Sept. 1937, No. 9, pp. 283–286.)

271. MEASUREMENT OF THE SCREENING ACTION OF A FARADAY CAGE AT BROADCAST FREQUENCIES.—W. Lampe & E. Ferroni. (*Physik. Zeitschr.*, 1st Sept. 1937, Vol. 38, No. 17, pp. 637–644.)

The double Faraday cage used is shown in Fig. 1 (plan of laboratory Fig. 2). The screening factor from outside to inside, which was the subject of the investigation, is defined as the ratio of the field strength at a fixed point outside the cage to that at the centre of the cage. The measurements were made with two different arrangements; the first used, at the receiver, unmodulated h.f. with h.f. amplification and an h.f. valve voltmeter. The second worked with modulated h.f., h.f. and l.f. amplification at the receiver, and a rectifier voltmeter as indicating instrument. Measurements were made with a local emitter and on the Deutschlandsender and Berlin. Figs. 6 and 7 show the cage attenuation [logarithm of the screening factor] and screening factor respectively, as functions of the frequency (range 100–1600 kc/s). The frequency of the greatest screening factor was found to be approximately the same as that of the local broadcasting emitter. The field distribution was much distorted by the leads in the laboratory and in the cage itself.

272. THE DETERMINATION OF THE INERTIA OF THERMOCOUPLES.—Levitskaja, Frankfurt, & Cherpakov. (*Journ. of Tech. Phys.* [in Russian], No. 11, Vol. 7, 1937, pp. 1194–1198.)

273. SUPERCONDUCTORS IN ALTERNATING MAGNETIC FIELDS [with Method of studying Magnetic Properties in Alternating Fields by measuring Change of Coil Inductance on Inserting Specimen], *and* AN A.C. METHOD OF MEASURING RESISTANCE [also by Change of Coil Inductance: Test for Superconductivity].—D. Shoenberg. (*Proc. Camb. Phil. Soc.*, Oct. 1937, Vol. 33, Part 4, pp. 559–576: pp. 577–582.)

274. MEASUREMENTS OF IONISATION IN GASES BY MEANS OF ALTERNATING CURRENT [Formation of Oscillating Space Charge gives Alternating Current large compared with That given by Normal Ionisation: Calculations: Measurements with A.C. Bridge].—H. W. Paehr. (*Zeitschr. f. Physik*, No. 11/12, Vol. 106, 1937, pp. 730–750.)

275. ANOMALIES OF SOLID DIELECTRICS [Theory assuming Validity of Superposition Principle: General Equation for Condenser Discharge: Its Solution: Method for determining Onset Current: Discussion of Phenomena and Their Importance for Measuring Technique: Experimental Verification].—B. Gross. (*Zeitschr. f. Physik*, No. 3/4, Vol. 107, 1937, pp. 217–234.)

276. TESTING AIRCRAFT APPARATUS AGAINST THE ELEMENTS, POWER DIVES, ETC.—General Electric Company. (*See* 159.)

SUBSIDIARY APPARATUS AND MATERIALS

277. CONTRAST EQUALISATION IN OSCILLOGRAMS WITH LARGELY VARYING RECORDING SPEED [Alberti's Method applied to Electrocardiograms, etc.].—Hollmann: Alberti. (*E.T.Z.*, 14th Oct. 1937, Vol. 58, No. 41, pp. 1118–1119.) For Alberti's method *see* 1516 of 1937: for Hollmann's work *see* 3977 of 1937.

278. THE DIMINUTION OF THE TRAPEZOIDAL ERROR IN CATHODE-RAY TUBES, *and* THE LIFE OF HOT CATHODES IN CATHODE-RAY TUBES.—Wigand: Reusse. (*See* 210 and 209.)

279. DERIVATION OF EXPRESSION FOR VOLTAGE ACROSS CAPACITANCE OF CATHODE-RAY OSCILLOGRAPH CIRCUIT, *and* THE DISPLACEMENT OF THE LINE OF ZERO VOLTAGE ON A CATHODE-RAY OSCILLOGRAM, DUE TO ACTION OF CAPACITIVE VOLTAGE-DIVIDER.—Peters & others. (*See* 98.)

280. THE APERTURE ERROR OF WEAK ELECTRON LENSES [Theoretical Comparison for Various Types of Lenses: Ring Lenses and Other Simple Types give Good Approximation to the Best Spherically Corrected Single Lens: High Quality Factor of Immersion Lens].—Rebsch & Schneider. (*Zeitschr. f. Physik*, No. 1/2, Vol. 107, 1937, pp. 138–143.) *See* also Scherzer, 4195 of 1936.

281. THIRD-ORDER IMAGE ERRORS OF THE SHORT, WEAK, PURELY ELECTRICAL, SINGLE ELECTRON LENS [Clear Form of Equations for Errors in Limiting Case].—Riedl. (*Zeitschr. f. Physik*, No. 3/4, Vol. 107, 1937, pp. 210–216.) Each error is expressed as a separate integral in eqn. 12.

282. THE APPLICATION OF THE ELECTRON LENS TO CLOUD CHAMBER PHOTOGRAPHY.—Davies & O'Ceallaigh. (*Proc. Camb. Phil. Soc.*, Oct. 1937, Vol. 33, Part 4, pp. 540–548.)

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283. Two Applications of Sommerfeld's Method of Branched Potentials [Theory of Boundary Effect of Circular Plate Condenser with Large Distance between Plates: Potential Field of Immersion Objective consisting of Disc-Shaped Cathode and Two Thin Wire Rings: Calculation of Voltages at Surface of Rings].—Waldmann. (*Physik. Zeitschr.*, 1st Sept. 1937, Vol. 38, No., 17 pp. 654–663.)

284. The Secondary Cathode Rays from Insulators [are not confined to a Limited Velocity Range of the Primary Rays: Assumption of Formation of Constant Potential in Insulator is False].—Katz. (*Zeitschr. f. Physik*, No. 1/2, Vol. 107, 1937, pp. 48–50.)

285. Distribution of the Secondary Electrons from Aluminium Netting [placed between Two Stops at Variable Voltages: Measurements of Electron Yield, etc.].—Hagen & Sandhagen. (*Zeitschr. f. Physik*, No. 1/2, Vol. 107, 1937, pp. 132–137.)

286. The Velocity Distribution of the Secondary Electrons produced in Gases by Cathode Rays [investigated by Lenard's Opposing Field Method: Velocity approximately Independent of Primary Velocity: Scattered Primary Electrons: Effect of Apparatus and Gas Pressure: No Tertiary Electrons observed].—Frey. (*Ann. der Physik*, Series 5, No. 3, Vol. 30, 1937, pp. 297–312.)

287. Absorption Measurements on Cathode Rays of Medium Velocity and Soft X-Rays in Oxygen.—Callisen. (*Zeitschr. f. Physik*, No. 1/2, Vol. 102, 1937, pp. 15–43.)

288. The Ionising Action of Cathode Rays in Various Gases and Gaseous Mixtures [Measurements for N_2, O_2, CO_2, SO_2, A, Ne, etc. in Cathode-Ray Velocity Range 10–40 kV: Determination of Differential Ionisation, etc.].—Gerbes. (*Ann. der Physik*, Series 5, No. 2, Vol. 30, 1937, pp. 169–183.)

289. On the Preparation of Bimetallic Plates of Zones and Rayleigh's Plates from Al for X-Ray Condensing Lenses.—Karchagin. (*Journ. of Tech. Phys.* [in Russian], No. 13, Vol. 7, 1937, pp. 1371–1373.)

290. Cement Phosphors [Preparation of a New Group of Highly Active Organic Phosphors with Long Duration of Phosphorescence: Addition of Salts improves Action: Emission Types: Colour Changes].—Travniček. (*Ann. der Physik*, Series 5, No. 3, Vol. 30, 1937, pp. 224–244.)

291. The Zinc Sulphide/Calcium Sulphide Phosphors [Preparation: Further Exchange of ZnS for CdS up to the Highest CdS Content: Spectral Intensity Distribution and Duration of Phosphorescence: Preparation of Phosphors with Given Colour and Phosphorescence Duration].—Kamm. (*Ann. der Physik*, Series 5, No. 4, Vol. 30, 1937, pp. 333–353.)

292. Experimental Study of the Triboluminescence of Certain Natural Crystals and Synthetically Prepared Materials.—Wick. (*Journ. Opt. Soc. Am.*, Aug. 1937, Vol. 27, No. 8, pp. 275–285.)

293. A Self-Fractionating Oil Diffusion Pump [giving Vacuum of 10^{-6} mm without Use of Vapour Traps].—Lockenvitz. (*Review Scient. Instr.*, Sept. 1937, Vol. 8, No. 9, pp. 322–323.)

294. A.C. Operation of an Ionisation Gauge.—Kuper. (*Review Scient. Instr.*, Oct. 1937, Vol. 8, No. 10, p. 394.)

295. Machined Metal Stuffing-Box Seals adapted to High Vacuum Technique.—Garner. (*Review Scient. Instr.*, Sept. 1937, Vol. 8, No. 9, pp. 329–332.)

296. A Source of Variable Rectangular Pulses [of Variable Strength and Duration, without Use of Mechanical Timing Accessories: Thyratron started by Positive Grid Surge and stopped by Succeeding Negative Grid Surge (from Second Thyratron): Max. Pulse Frequency (for Constancy of Duration) about 5 per Sec.].—Peugnet. (*Review Scient. Instr.*, Sept. 1937, Vol. 8, No. 9, pp. 340–342.)

297. Study of the Discharge of a Condenser across a Gas-Filled Tube [Theory in which Tube is not regarded as having Constant Resistance: Calculation of Residual Charge on Condenser]. — Bethenod. (*Comptes Rendus*, 26th Oct. 1937, Vol. 205, No. 17, pp. 727–730.) *See* also 4301 (also 2749) of 1937.

298. Stroboscope for Aperiodic Phenomena [Observations of Gas Discharges, Sparks, etc.].—Schiller. (*Zeitschr. f. tech. Phys.*, No. 10, Vol. 18, 1937, pp. 332–336.)

299. On Rotating Mirrors at High Speed.—Boys. (*Proc. Roy. Soc. Edinburgh*, Part 3, Vol. 57, 1937, pp. 377–378.)

300. Propagation of Potential in Discharge Tubes.—Snoddy, Dietrich & Beams. (*See* 43.)

301. A Photographic Study of the Vacuum Spark Discharge [Luminosity appears first at Anode: Motion of Positive Ions: Hypotheses of Discharge Mechanism].—Chiles. (*Journ. of Applied Physics*, Sept. 1937, Vol. 8, No. 9, pp. 622–626.)

302. The Employment of Electronic Regulators for the Control of Mercury-Vapour Rectifiers.—Jungmichl & Kottenhahn. (*Rev. Gén. de l'Élec.*, 9th Oct. 1937, Vol. 42, No. 15, pp. 477–478: long summary only.)

303. Sputtering of Thermionic Cathodes in Mercury-Vapour Diodes.—Morgulis & Patiocha. (*See* 145.)

304. A Graphic Representation of the Power Dissipation at the Anode of a Thermionic Rectifier.—Rabinovich. (*See* 66.)

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305. High-Voltage Transmitter Supply Unit.—Dent. (*See* 93.)

306. Selenium Couple with Cadmium Selenide Boundary Layer: Application as Rectifier.—Lindblad & Liljeblad. (*See* 359.)

307. Ageing of Copper-Oxide Rectifiers.—Sharavski. (*Journ. of Tech. Phys.* [in Russian], No. 11, Vol. 7, 1937, pp. 1189–1193.)

A report on an experimental investigation to determine the causes of the ageing of rectifiers (falling off of the rectified current). A number of rectifiers using different upper electrodes were investigated and the results seem to indicate that ageing is caused by heating of the rectifier and that, provided the rectifier is not allowed to warm up, an electric current can be passed through it for a considerable time without affecting its rectification properties. It is suggested that falling off of the rectified current is due to increased resistance of the copper-oxide layer, a suggestion which was confirmed by additional experiments with copper-oxide plates. For previous work on these rectifiers *see* 350 & 4289 of 1937.

308. Progress in the Construction of Copper-Oxide Rectifiers.—Smith. (*Electric Journal*, Vol. 34, 1937, pp. 205–209.)

309. "Descriptive Pamphlets relating to Metal Rectifiers."—Westinghouse Company. (At Patent Office Library, London: Cat. No. 77 799: Series in progress.)

310. A Method for Improving the Zero-Point Stability of Multiple-Stage Push-Pull D.C. Amplifiers.—Neilsen. (*See* 63.)

311. The Magnetic Amplifier.—K. Vulfson. (*Journ. of Tech. Phys.* [in Russian], No. 11, Vol. 7, 1937, pp. 1170–1174.)

A description of a magnetic amplifier suitable for amplification of small slowly varying voltages was published in *Siemens-Zeitschrift*, Vol. 15. This amplifier consists of four transformers the windings of which (there are four windings on each transformer) are connected into the following four groups (Fig. 1). Group 1 to which the voltage to be amplified is applied, Group 2 which maintains a constant magnetic field, Group 3 which maintains an alternating magnetic field of intensity $A \sin \omega t$, and Group 4 from which the amplified voltage is taken. In the present paper a formula (11) is derived determining the amplified voltage, and optimum values of the constant magnetic field and of A are found for the cases when the amplifier is followed by either a thermionic valve or a thyratron. The amplification factor is also calculated for each of the above cases, and the discussion is illustrated by numerical examples.

312. Compressed Powder Cores for H.F. Coils [Use of Iron Carbide and Magnetite to give Low Damping (proportional to Initial Permeability and Electric Conductivity) without Too Great Reduction of Total Permeability].—R. Bosch Company. (French Pat. 813 042, pub. 25.5.1937: *Rev. Gén. de l'Élec.*, 30th Oct. 1937, Vol. 42, No. 18, p. 141D.)

313. The Vibration Magnetometer [for Fields of 1–30 000 Gauss: Small Vibrating (Motor-Driven) Search Coil, Valve Amplifier, and Rectifier-Type Voltmeter].—Groszkowski. (*Journ. Scient. Instr.*, Oct. 1937, Vol. 14, No. 10, pp. 335–339.) *Cf.* Gilloux, 564 of 1937.

314. The Magnetic Properties of Austenite Steels before and after Nitriding.—Kuznecov. (*Journ. of Tech. Phys.* [in Russian], No. 13, Vol. 7, 1937, pp. 1374–1380.)

315. The Design of Powerful Electro-Magnets: Part III—The Use of Iron.—Bitter. (*Review Scient. Instr.*, Sept. 1937, Vol. 8, No. 9, pp. 318–319.) Correction and supplement to Part I (1234 of 1937).

316. A Half-Cycle Magnetiser with Thyratron Control.—Lord. (*Gen. Elec. Review*, Sept. 1937, Vol. 40, No. 9, pp. 418–420.)

317. Volume Magnetostriction of Iron and Nickel.—Snoek. (*Physica*, Oct. 1937, Vol. 4, No. 9, pp. 853–862: in English.)

318. Magnetic Properties of Alloys of Iron with Iridium.—Fallot. (*Comptes Rendus*, 20th Sept. 1937, Vol. 205, No. 12, pp. 517–518.)

319. Magnetic Properties of Iron/Rhodium Alloys [Mean Atomic Moment increases with Rhodium Content].—Fallot. (*Comptes Rendus*, 4th Oct. 1937, Vol. 205, No. 14, pp. 558–560.)

320. Magnetic Properties of Single Crystals of Silicon Iron [Measurements: Anisotropy at Low Magnetisations].—Williams. (*Phys. Review*, 1st Oct. 1937, Series 2, Vol. 52, No. 7, pp. 747–751.)

321. The Magnetic Properties of Iron Amalgams.—Bates & Illsley. (*Proc. Phys. Soc.*, 1st Sept. 1937, Vol. 49, Part 5, No. 275, pp. 611–618.)

322. Saturation Magnetisation and Approximation Law of Iron [Measurements on Various Kinds of Iron by Absolute Methods].—Steinhaus, Kussmann, & Schoen. (*Physik. Zeitschr.*, 15th Oct. 1937, Vol. 38, No. 20, pp. 777–785.)

323. Energy of Lattice Distortion in Cold Worked Permalloy [X-Ray Measurements].—Haworth. (*Phys. Review*, 15th Sept. 1937, Series 2, Vol. 52, No. 6, pp. 613–620.)

324. The Natural Magnetism of Crystals [Measurements show Permanent Magnetisation of Gypsum Crystals, in Direction of Principal Axis, agreeing with Vogt's Theory: Much Smaller Effect with Quartz Glass: Effect in Agreement with Diamagnetic Permeability].—Krüger & Brosack. (*Ann. der Physik*, Series 5, No. 2, Vol. 30, 1937, pp. 113–135.)

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325. MAGNETIC ANISOTROPY OF RARE EARTH SULPHATES AND THE ASYMMETRY OF THEIR CRYSTALLINE FIELDS [Measurements of Anisotropy: Deduction of Asymmetry].—Krishnan & Mookherji. (*Nature*, 25th Sept. 1937, Vol. 140, p. 549.)

326. CRYSTAL STRUCTURE AND ELECTRICAL PROPERTIES: VII—THE ANISOTROPY IN THE ELECTRICAL CONDUCTIVITY OF CRYSTALLINE BISMUTH [with Effect of Magnetic Field].—Stierstadt. (*Zeitschr. f. Physik*, No. 1/2, Vol. 107, 1937, pp. 51–63.)

327. ERRATA: MAGNETIC INTERACTION AND RESULTANT ANISOTROPY IN STRAINED FERROMAGNETIC CRYSTALS [Corrections of Calculation Errors].—McKeehan. (*Phys. Review*, 1st Sept. 1937, Series 2, Vol. 52, No. 5, p. 527.) *See* 3884 of 1937.

328. DIRECTIONAL FERROMAGNETIC PROPERTIES OF METALS [Résumé of Recent Work, Theory of Anisotropy, Effects of Composition of Alloys and Stress, Single Crystal Results, etc.].—Bozorth. (*Journ. of Applied Physics*, Sept. 1937, Vol. 8, No. 9, pp. 575–588.)

329. THE DIAMAGNETIC SUSCEPTIBILITIES OF DISSOLVED AND HYDRATED SALTS.—Hoare & Brindley. (*Proc. Phys. Soc.*, 1st Sept. 1937, Vol. 49, Part 5, No. 275, pp. 619–628.)

330. SOME PRACTICAL DATA RELATIVE TO THE COMPONENTS OF [Broadcast] RADIOELECTRIC RECEIVERS.—Adam. (*See* 105.)

331. THE FACTOR OF MERIT OF SHORT-WAVE COILS.—Michel. (*See* 54.)

332. THE DESIGN OF INDUCTANCE FOR FREQUENCIES BETWEEN 4 AND 25 MEGACYCLES.—Pollack. (*See* 104.)

333. MEASUREMENT OF THE SCREENING ACTION OF A FARADAY CAGE AT BROADCAST FREQUENCIES.—Lampe & Ferroni. (*See* 271.)

334. TEMPERATURE VARIATION OF ROTATING CONDENSERS WITH AIR DIELECTRIC.—Gohlke. (*See* 264.)

335. ANOMALIES OF SOLID DIELECTRICS.—Gross. (*See* 275.)

336. "ELECTROLYTIC CONDENSERS: THEIR PROPERTIES, DESIGN AND PRACTICAL USES" [Book Review].—P. R. Coursey. (*Journ. Scient. Instr.*, Oct. 1937, Vol. 14, No. 10, p. 354.)

337. ELECTROLYTIC CONDENSERS [Basic Principles: Details of Manufacturing Methods].—Pirie. (*Wireless World*, 1st & 8th Oct. 1937, Vol. 41, pp. 326–329 & 358–360.)

338. THE DEVELOPMENT OF LOW-VOLTAGE PAPER CONDENSERS.—Walther & Inge. (*Izvestiya Elektroprom. Slab. Toka*, 1937, No. 5/6, pp. 52–59, and No. 7, pp. 47–52.) A detailed report on an investigation of the various processes in the manufacture of paper condensers. The investigation was undertaken in order to raise the quality of the condensers manufactured in Russia from local materials.

339. MICA CONDENSERS OF STABLE CAPACITY.—Renne & Mukhlynin. (*See* 86.)

340. THE ADSORBED MOISTURE FILMS ON THE SURFACE OF GLAZED PORCELAIN [Changes under Influence of Alternating Voltage Stresses and Surface Temperatures: Leakage Film, if continuous, has Two Components, One Adsorbed, the other a Surface Solution: Constant Proportional Equilibrium between These Two Parts].—Johnson. (*Phil. Mag.*, Nov. 1937, Series 7, Vol. 24, No. 163, pp. 797–807.)

341. SOME PROBLEMS OF PHYSICS IN THE APPLICATION OF DIELECTRICS AS INSULATORS [General Account: Dipoles in Insulators, Dielectric Breakdown, Behaviour of Electrons in Dielectrics, etc: Apparent Dielectric Strength of Materials may be due to Mechanisms at Metal/Insulator Boundary as well as to Dielectric Material Itself].—Hill. (*Journ. of Applied Physics*, Sept. 1937, Vol. 8, No. 9, pp. 607–613.)

342. INVESTIGATION OF AMORPHOUS STATE: XI—ELASTICITY [including Hardening of Soft and Hard Rubber, etc.].—Kobeko & others. (*Tech. Phys. of USSR*, No. 8, Vol. 4, 1937, pp. 622–637: in English.)

343. DIRECTIONS FOR THE STUDY OF HARD COMPOSITE DIELECTRICS (MOULDINGS, SHEET, AND THE LIKE).—E. R. A. (*Journ. I.E.E.*, Oct. 1937, Vol. 81, No. 490, pp. 553–564.) Report Ref. B/S3 of the British Electrical & Allied Industries Research Association.

344. DIELECTRIC STRENGTH OF INSULATING FLUIDS: PART I—ELECTRIC BREAKDOWN STRENGTHS OF CERTAIN GASES AND GAS-VAPOUR MIXTURES.—Charlton & Cooper. (*Gen. Elec. Review*, Sept. 1937, Vol. 40, No. 9, pp. 438–442.)

345. PAPERS ON THE ABSORPTION AND DISPERSION OF MICRO-WAVES IN LIQUIDS.—(*See* 251/252.)

346. INVESTIGATIONS ON THE H.F. RESISTANCE OF THIN-FILM RESISTANCES.—Strack. (*See* 211.)

347. VARIABLE-PRESSURE CARBON RESISTANCES [for Machine Regulation, Telemetering, etc.].—Hoffmann. (*E.T.Z.*, 14th and 21st Oct. 1937, Vol. 58, Nos. 41 and 42, pp. 1111–1115 and 1138–1142.)

348. TIME-LAG IN A CONTROL SYSTEM: II.—Hartree, Porter, Callender, & Stevenson. (*Proc. Roy. Soc.*, Series A, 20th Aug. 1937, Vol. 161, No. 907, pp. 460–476.) Extension to more general control law of work dealt with in 4214 of 1936.

349. A RELAY FOR KEEPING MAGNET CURRENTS CONSTANT [Circuit of Valve Relay for Smoothing Mains Variations].—L. Leiterer. (*Physik. Zeitschr.*, 15th Aug. 1937, Vol. 38, No. 16, pp. 626–627.)

350. A "SCALE-OF-TWO" HIGH-SPEED COUNTER USING HARD VACUUM TRIODES [Circuit: "Watch-Dog" Thyratron Recording Circuit].—Lewis. (*Proc. Camb. Phil. Soc.*, Oct. 1937, Vol. 33, Part 4, pp. 549–558.)

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351. THE PROPERTIES AND INDUSTRIAL USES OF SILVER [and Its Alloys].—Rogers, Schoonover, & Jordan. (*Rev. Gén. de l'Élec.*, 23rd Oct. 1937, Vol. 42, No. 17, pp. 541–542.) Summary of a National Bureau of Standards (U.S.A.) circular.

352. THE FORMATION OF METALLIC BRIDGES IN SEPARATED CONTACTS [Field required to form Low Resistance Bridges between Electrodes: Electrostatic Force pulls Material from Electrodes to bridge Gap].—Pearson. (*Phys. Review*, 1st June 1937, Series 2, Vol. 51, No. 11, p. 1015: abstract only.)

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STATIONS, DESIGN AND OPERATION

354. THE STAGSHAW TRANSMITTING STATION.—B.B.C. (At Patent Office Library, London: Cat. No. 78 013: 14 pp.)

355. WIRED-WIRELESS IN GERMANY [Broadcasting over Telephone Lines].—Gladenbeck. (*Wireless World*, 1st Oct. 1937, Vol. 41, p. 341.)

356. SPECIAL EMERGENCY STATION [Los Angeles County Flood Control District Network].—Kennedy. (*Communications* [Merger of *Rad. Engineering* and *Communication & Broadcast Engineering*], Sept. 1937, Vol. 17, No. 9, pp. 18–19.)

357. MERRILL-LAMBIE COMMERCIAL TRANSATLANTIC FLIGHT [New-York/London 5-Day Round Trip in "Daily Express": Wireless Equipment].—McClary. (*Communications* [see 356], Sept. 1937, Vol. 17, No. 9, pp. 38 and 62, 63.)

358. INDIANA'S POLICE-RADIO SYSTEM.—(*Communications* [see 356], Sept. 1937, Vol. 17, No. 9, pp. 22–23.)

GENERAL PHYSICAL ARTICLES

359. IS THE SECOND LAW OF THERMODYNAMICS GENERALLY VALID FOR MACROSCOPIC PROCESSES? [Selenium Couple with Cadmium Selenide Boundary Layer apparently emits Current without Supply of Energy, forming System with Decreasing Entropy: Possible Application to Rectifiers: Theoretical Discussion].—Lindblad & Liljeblad. (*Ingeniörs Vetenskaps Akadamien Handlingar*, No. 145, 1937, pp. 3–14: in English.)

360. CONDUCTIVITY OF GASES AT HIGH PRESSURES [Some Gases become Conductive at Fields 10 Thousand Times smaller than Those necessary for Spontaneous Ionisation].—Clay, von Kleef, & von Tijn. (*Physica*, Oct. 1937, Vol. 4, No. 9, p. 766: in English.)

361. THE DETERMINATION OF THE TOWNSEND IONISATION COEFFICIENT α, TAKING INTO CONSIDERATION THE VARIOUS ELEMENTARY PROCESSES [Elastic and Inelastic Losses, Collisions of the Second Kind: for Pure Gases and Mixtures].—Moralev. (*Physik. Zeitschr. der Sowjetunion*, No. 1, Vol. 12, 1937, pp. 89–104: in German.)

362. THE MOBILITY AND MEAN FREE PATH OF ELECTRONS IN THE POSITIVE COLUMN [and the Relaxation Time of the Plasma].—Gvosdover. (*Physik. Zeitschr. der Sowjetunion*, No. 2, Vol. 12, 1937, pp. 164–181: in English.)

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364. VELOCITY ANALYSIS [of Molecules in Molecular Beam] BY MEANS OF THE STERN-GERLACH EFFECT.—Cohen & Ellett. (*Phys. Review*, 1st Sept. 1937, Series 2, Vol. 52, No. 5, pp. 502–508.)

365. INCREASE OF NEGATIVE PHOTOPHORESIS BY A HIGH-FREQUENCY ELECTRIC FIELD (PRELIMINARY COMMUNICATION).—Groetzinger. (*Physik. Zeitschr.*, 1st Oct. 1937, Vol. 38, No. 19, pp. 766–767.)

MISCELLANEOUS

366. THE "CONVERGING FACTOR" IN ASYMPTOTIC SERIES AND THE CALCULATION OF BESSEL, LAGUERRE, AND OTHER FUNCTIONS.—Airey. (*Phil. Mag.*, Oct. 1937, Series 7, Vol. 24, No. 162, pp. 521–552.)

367. ON BESSEL PRODUCT FUNCTIONS [Hypergeometric Nature: Operational Representation].—Humbert. (*Phil. Mag.*, Nov. 1937, Series 7, Vol. 24, Supp. No. 164, pp. 888–890.) For definition of these functions *see* 1634 of 1936 (Costello).

368. DEGREE OF APPROXIMATION BY POLYNOMIALS.—PROBLEM α.—Sewell. (*Proc. Nat. Acad. Sci.*, Sept. 1937, Vol. 23, No. 9, pp. 491–493.)

369. ON THE SMOOTHING OF OBSERVED DATA [Method for Removal of Random Errors before Interpolation].—Jeffreys. (*Proc. Camb. Phil. Soc.*, Oct. 1937, Vol. 33, Part 4, pp. 444–450.)

370. THE SHOT EFFECT FOR SHOWERS [Theory: Average Number of Events in Given Time: Mean Square of Fluctuation].—Whittaker. (*Proc. Camb. Phil. Soc.*, Oct. 1937, Vol. 33, Part 4, pp. 451–458.)

371. "WAHRSCHEINLICHKEITEN UND SCHWANKUNGEN" [including Application of Statistical Methods to Manufactured Products, Telephony, Geophysical Research, etc.: Book Review].—Lubberger (Edited by). (*E.T.Z.*, 11th Nov. 1937, Vol. 58, No. 45, p. 1230.)

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372. PROBABILITY EXPERIMENTALLY INVESTIGATED. —Clark. (*Canadian Journ. of Res.*, Sept. 1937, Vol. 15, No. 9, Sec. A, pp. 149–153.)

373. TESTS FOR RANDOMNESS IN A SERIES OF NUMERICAL OBSERVATIONS, *and* SOME DISTRIBUTIONS ASSOCIATED WITH A RANDOMLY ARRANGED SET OF NUMBERS.—Kermack & McKendrick. (*Proc. Roy. Soc. Edinburgh*, Part 3, Vol. 57, 1937, pp. 228–240: pp. 332–376.)

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375. TRANSMISSION OF RADIANT ENERGY THROUGH THE ATMOSPHERE [Signalling through Fog, Snow, etc., by Use of Hayes Radiometer, Sensitive to Wavelengths from Ultra-Violet to 15 Microns].—Hayes. (*Review Scient. Instr.*, Sept. 1937, Vol. 8, No. 9, pp. 342–345.) *See* also 2854 of 1936.

376. THE MEASUREMENT OF THE SIZE AND CHARGE OF DUST AND FOG PARTICLES.—Rosenblum. (*Tech. Phys. of USSR*, No. 7, Vol. 4, 1937, pp. 564–568: in German.)

377. NEW EXPERIMENTAL METHODS [connected with Wave-Guide Technique] APPLICABLE TO ULTRA-SHORT WAVES.—Southworth. (*See* 41.)

378. "OLD WIRES AND NEW WAVES" [Story of Electrical Communications, including Political, Financial, and Purely Human Sides: Book Review].—Harlow. (*Review Scient. Instr.*, Oct. 1937, Vol. 8, No. 10, pp. 358–359.) A very enthusiastic review.

379. FOURTH MEETING OF THE C.C.I.R. [at Bucharest: including Resolution No. 85, Proposed Classification of Waves and Frequencies (Wavelengths from over 10 000 m to 1 cm) into 7 Classes each)].—(*Alta Frequenza*, Oct. 1937, Vol. 6, No. 10, pp. 686–691.) Thus waves between 100 m and 1000 m are classified as "hectometre" waves; between 1000 m and 10 000 m as "kilometre" waves.

380. THE ORIGIN AND DEVELOPMENT OF RADIO-TELEPHONY, *and* TRANSOCEANIC RADIO-TELEPHONE DEVELOPMENT.—Espenschied: Bown. (*Proc. Inst. Rad. Eng.*, Sept. 1937, Vol. 25, No. 9, pp. 1101–1123: pp. 1124–1135.)

381. ELECTROMAGNETIC METHOD FOR TESTING ROCK-SAMPLES.—McNish. (*Terr. Mag. & Atmos. Elec.*, Sept. 1937, Vol. 42, No. 3, pp. 283–284.)

382. THE FUNDAMENTAL THEOREM OF APPLIED GEOPHYSICS.—Löwy. (*Terr. Mag. & Atmos. Elec.*, June 1937, Vol. 42, No. 2, pp. 159–162.)

383. RADIO ENGINEERING IN THE VDE TECHNICAL REPORTS.—Schwandt. (*Funktech. Monatshefte*, Oct. 1937, No. 10, pp. 325–327.)

Iron-powder coils with Q-values up to 740 at 80 kc/s: porous ceramic insulating materials: researches on earths: AEG pointer-type (condenser charging) frequency meter up to 60 kc/s: etc.

384. "MITTEILUNGEN AUS DEM REICHSPOST-ZENTRALAMT: BAND XIX" [Book Review].—(*E.T.Z.*, 11th Nov. 1937, Vol. 58, No. 45, p. 1230.) Containing 56 papers (1935, 1936, and beginning of 1937) on television, common-wave broadcasting, receiver testing, processes in thermionic valves, etc.

385. THE ACTIVITIES OF THE PHYSIKALISCH-TECHNISCHE REICHSANSTALT DURING 1936 [Gold/Chrome Alloys for Precision Resistances: Series connection of Variable Condensers (for Ultra-Short-Wave Meter) giving 2.5 pF Initial and 100 pF Full Capacity: Current Measurements at Very High Frequencies: etc.].—(*E.T.Z.*, 16th Sept. 1937, Vol. 58, No. 37, pp. 1015–1016: summary only.) The full paper is in *Physik. Zeitschr.*, Vol. 38, 1937, p. 225.

386. THE RESEARCH ESTABLISHMENT OF THE GERMAN STATE POST OFFICE [and Its Formation in January 1937].—Flanze. (*T.F.T.*, May 1937, Vol. 26, No. 5, pp. 97–98.)

387. GERMAN ELECTRICAL IMPORTS AND EXPORTS, JAN./JUNE 1937.—(*E.T.Z.*, 16th Sept. 1937, Vol. 58, No. 37, pp. 1019–1020.)

388. FRENCH IMPORTS AND EXPORTS IN THE FIRST SIX MONTHS OF 1937.—Revval. (*Rev. Gén. de l'Élec.*, 16th Oct. 1937, Vol. 42, No. 16, pp. 499–511.)

389. CONCERNING THE WORK OF THE LENINGRAD PHYSICAL-TECHNICAL INSTITUTE IN 1936 AND THE DIRECTION OF THE WORK IN 1937.—Hochberg. (*Tech. Phys. of USSR*, No. 6, Vol. 4, 1937, pp. 505–507.)

Work on semiconductors and on amorphous bodies (*e.g.* rubber) form 2 out of the 4 items of the programme. In 1937 the work on semiconductors is directed towards improved types of solid rectifiers for small voltages and high frequencies, and for heavy current and high voltage: new solid rectifiers using the properties of oxides, sulphides, and selenides: barrier-layer photocells of increased efficiency and of maximum sensitivity in the infra-red: methods of mass production of selenium photocells.

390. THE MARCONI SCHOOL OF WIRELESS COMMUNICATION: HISTORICAL SURVEY, GENERAL LAYOUT, AND EQUIPMENT.—Dowsett. (*Marconi Review*, May/Aug. 1937, No. 66, pp. 1–14.)

391. THE "PAVILLON DE LA RADIO" AT THE PARIS EXPOSITION, 1937.—Adam. (*Génie Civil*, 18th Sept. 1937, Vol. 111, No. 12, pp. 247–250.)

392. THEORY OF THE IRRADIATION OF STRATIFIED BIOLOGICAL OBJECTS WITH ULTRA-SHORT AND MICRO-WAVES.—Hollman. (*See* 40.)

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Some Recent Patents

The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each.

AERIALS AND AERIAL SYSTEMS

469 366.—Television aerial consisting of two conical-shaped radiators arranged as the upper and lower limbs of a dipole.

Standard Telephones and Cables (communicated by Le Materiel Telephonique Soc. Anon.). Application date 4th December, 1936.

469 589.—Bi-directional aerial, particularly suitable for ships, and designed to have a substantially constant impedance over the working range of frequencies.

Standard Telephones and Cables (assignees of A. Alford). Convention date (U.S.A.) 17th March, 1936.

471 434.—Television receiving aerial combined with a lightning protector which also forms part of a rejector circuit for preventing leakage currents along the feed-line.

K. H. Barbour. Application date 3rd March, 1936.

472 534.—Short-wave aerial consisting of two parallel conductors arranged to suppress alternate half-waves.

Telefunken Co. Convention date (Germany) 28th April, 1936.

474 384.—Half-wave aerial with an artificial "top" consisting of a number of wires symmetrically arranged with relation to the down lead.

Marconi's W.T. Co. and N. Wells. Application date, 29th April, 1936.

DIRECTIONAL WIRELESS

469 775.—Method of keying wireless beams used to assist an aviator to make a "blind" landing.

D. N. Sharma. Application date 7th February, 1936.

470 165.—Method of keying the radio-beams used to produce a predetermined course for assisting the navigation or blind-landing of aeroplanes.

Telefunken Co. Convention date (Germany) 6th January, 1936.

472 111.—Combining the signal pick-up from a directional and non-directional aerial in a common amplifier, so as to indicate the direction from which the signals are arriving.

F. J. Hooven. Application date 14th December, 1935.

473 167.—Direction-finding system in which a rotating field pattern is radiated and the bearings are ascertained by a method of "counting" the received signal impulses.

C. Lorenz Akt. Convention dates (Germany) 12th December, 1935, and 19th May, 1936 (addition to 447 707).

473 807.—Directive system for guiding an aeroplane to the aerodrome and effecting a "blind" landing of the machine.

Standard Telephones and Cables (assignees of Le Materiel Telephonique). Convention date (France) 31st December, 1935.

474 380.—Direction-finding equipment with automatic means for offsetting the rolling or pitching motion of a ship at sea.

Marconi's W.T. Co. and G. M. Wright. Application date 29th April, 1936.

RECEIVING CIRCUITS AND APPARATUS

(See also under Television).

469 428.—Superhet receiver in which a variable coupling interposed between the local oscillator and mixer is used to provide automatic volume control.

J. Robinson. Application date 25th January, 1936.

469 472.—Push-pull arrangement of peak rectifiers for modulation and demodulation.

F. C. Williams. Application date 24th October, 1935.

469 670.—Tuning system for a receiver fitted with means for suppressing inter-channel noise.

E. K. Cole and G. Bradfield. Application date 30th January, 1936.

470 002.—Method of suppressing "image frequencies" in a superhet receiver.

P. A. Le Marchant. Application date 31st January, 1936.

470 131.—Circuit for receiving phase or frequency modulated signals by using a multi-grid detector.

Marconi's W.T. Co. (assignees of M. G. Crosby). Convention date (U.S.A.) 6th June, 1935.

470 140.—Method of reducing the effect of artificial static by creating "gaps" in the sequence of signals coincident with the impact of the interference.

W. S. Percival. Application dates 8th November, 1935, and 9th April, 1936.

470 301.—Means for suppressing "static" interference radiated from the flashing lights used for advertising and display purposes.

General Electric Co.; N. R. Bligh; and H. G. Lillicrap. Application date 19th June, 1936.

470 366.—Single-valve unit designed to function as a combined radio transmitter and receiver.

E. K. Cole. Application date 12th May, 1936.

470 372.—Automatic selectivity control system in which the regulation is effected by a current derived from the low-frequency side of the set.

Telefunken Co. Convention date (Germany) 22nd January, 1936.

470 450.—Superhet receiver in which the width of one of the two signal side-bands is varied relatively to that of the other in order to reduce interference.

Hazletine Corpn. Convention date (U.S.A.) 28th January, 1936.

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470 597.—Tuning indicator in which an illuminated image is projected on to the dial without any background shadows.

Philco Radio and Television Corpn. Convention date (U.S.A.) 27th April, 1936.

470 736.—Remote-control tuning system adapted to be operated by an automatic dialling switch.

Standard Telephones and Cables (assignees of Le Materiel Telephonique). Convention date (France) 8th February, 1936.

470 805.—Receiver of the cathode-ray type for detecting ultra-short waves of the order of centimetres.

Marconi's W.T. Co. (assignees of E. G. Linder). Convention date (U.S.A.) 31st December, 1935.

471 065.—Feed-back circuit for eliminating second-channel interference in a superhet receiver.

J. Robinson. Application date 24th February, 1936.

471 306.—Pentagrid-converter or similar single-valve "mixer" for use on an all-wave receiving set.

Marconi's W.T. Co. Convention date (U.S.A.) 31st January, 1935.

471 738.—Means for stabilising the frequency of the local-oscillator valve in a superhet receiver.

Marconi's W.T. Co. Convention date (U.S.A.) 4th February, 1935.

471 796.—Tuning dial associated with the loud-speaker opening in a wireless cabinet.

J. A. Dreyfus. Convention date (U.S.A.) 6th December, 1934.

471 812.—Automatic volume control system in which high-frequency waves are fed to the low-frequency stages of the set where they are amplified and rectified, and the D.C. voltage fed back for A.V.C.

Kolster-Brandes and H. K. Robin. Application date 10th March, 1936.

471 982.—Reactive couplings for automatically varying the selectivity of a superhet receiver.

Hazletine Corporation (assignees of W. Lyons). Convention date (U.S.A.) 22nd April, 1935.

TELEVISION CIRCUITS AND APPARATUS

FOR TRANSMISSION AND RECEPTION.

469 127.—Cathode-ray television receiver in which several separate cathodes are arranged in one container in order to increase the intensity of the spot of light produced on the fluorescent screen.

E. Michaelis.

469 427.—Optical device or light-beam "transformer" for use in television scanning.

Scophony and J. H. Jeffree. Application date 25th January, 1936.

469 558.—Cathode-ray tube provided with a screen the transparency of which is controlled by the electron stream.

M. Harman. Convention date (Austria) 25th January, 1935.

469 628.—Earthing connections for a short-wave television transmitter.

Radio-Akt. D. S. Loewe. Convention date (Germany) 30th April, 1935.

469 673.—Scanning device in which the aperture is given a real or apparent displacement in order to correct for trapezoidal distortion.

Baird Television and J. L. Baird. Application date 30th January, 1936.

469 791.—Amplifying circuit for handling a wide band of frequencies, such as are used in television.

N. V. Philips Co. Convention date (Germany) 11th November, 1935.

469 813.—Amplifier designed to transmit the so-called "zero" frequency in television.

British Thomson-Houston Co. and J. Moir. Application date 31st January, 1936.

469 823.—Method of making a photo-electric "mosaic" screen as used in a cathode-ray television transmitter.

H. E. Holman. Application date 1st February, 1936.

469 897.—Focusing system in a cathode-ray tube of the kind in which the primary stream of electrons is amplified by secondary emission.

Marconi's W.T. Co. and N. Levin. Application date 3rd February, 1936.

469 907.—Cathode-ray television receiver utilising a screen with persistent "afterglow."

E. Michaelis (communicated by E. Kinne). Application date 6th February, 1936.

470 347.—Light cell for television scanning in which crystals in colloidal suspension are orientated by the action of an electric or magnetic field.

Baird Television and J. L. Baird. Application date 13th February, 1936.

470 496.—Electrode arrangement for concentrating the electron stream in a cathode-ray television receiver.

Radio-Akt. D. S. Loewe. Convention date (Germany) November 20th, 1934.

470 623.—Construction of cabinet for a combined sound and cathode-ray television receiver.

Ideal Werke Akt. Convention date (Germany) 14th March, 1936.

470 729.—Stabilising the operation of an amplifier designed to handle a wide band of frequencies, as in television.

Telefon-Akt. L. M. Ericsson. Convention date (Sweden) 19th September, 1935.

470 752.—Back-coupled saw-toothed oscillation-generator for use with a cathode-ray television receiver.

Telefunken Co. Convention date (Germany) 20th December, 1934.

470 785.—Eliminating from a television receiver, of the electron-camera type, disturbances created during the fly-back period of scanning.

Baird Television and V. A. Jones. Application date 21st February, 1936.

470 885.—Improving the optical qualities of a cathode-ray tube of the Iconoscope type.

Corning Glass Works. Convention date (U.S.A.) 18th July, 1936.

470 920.—Arrangement of the illuminated control indicators on a television receiver.

Baird Television and L. R. Merdler. Application date 24th February, 1936.

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470 922.—Saw-toothed oscillation generator for producing scanning currents of considerable amplitude.

Baird Television and D. M. Johnstone. Application date 24th February, 1936.

471 066.—Scanning system for television in which a beam of light is passed through a transparent medium subjected to mechanical waves of supersonic frequency.

Scophony and G. Wikkenhauser. Application date 26th February, 1936.

471 103.—Magnetic deflecting system for correcting the so-called "pincushion" distortion in cathode-ray scanning.

M. Bowman-Manifold. Application date 27th November, 1935.

471 109.—Mosaic-cell electrodes for use in cathode-ray television transmitters.

Marconi's W.T. Co. Convention date (U.S.A.) 30th January, 1935.

471 149.—Means for preventing undesired secondary emission from the mosaic cell electrode of a cathode-ray television transmitter.

Marconi's W.T. Co. Convention date (U.S.A.) 30th January, 1935.

471 185.—Time-base circuit for television scanning designed to produce a rapid and regular fly-back stroke.

Standard Telephones and Cables and R. M. Barnard. Application date 28th February, 1936.

471 190.—Method of preparing Willemite fluorescent screens suitable for cathode-ray television receivers.

Marconi's W.T. Co. Convention date (U.S.A.) 28th February, 1935.

471 199.—Electrode arrangement for image-dissector tubes of the secondary emission type as used in television.

Farnsworth Television Inc. Convention date (U.S.A.) 12th March, 1935.

471 337.—Single-valve oscillation-generator of the multi-vibrator type suitable for television scanning.

H. R. Lubcke. Application date 25th May, 1936.

471 365.—Light-sensitive device in which a photo-electric cathode co-operates with a fluorescent screen to amplify the light intensity of a televised picture.

Telefunken Co. Convention date (Germany) 1st March, 1935.

471 539.—Television receiver in which an electron image is first formed and is then enlarged by electrostatic or electromagnetic fields of force.

Baird Television; C. Szegho; and D. M. Johnstone. Application date 5th March, 1936.

471 696.—Arrangement for ensuring the correct application of scanning voltages to the deflection plates of a cathode-ray tube.

The Plessy Co. and C. E. G. Bailey. Application date 21st May, 1936.

471 737.—Saw-toothed oscillation generators of the blocking type for use in television scanning.

C. L. Faudell and E. L. C. White.

471 747.—Method of polarising light-rays, particularly for use in television.

Radio-Akt. D. S. Loewe. Convention date (Germany) 11th March, 1935.

471 913.—Mosaic-cell or "storage" electrodes for cathode-ray television transmitters of the Iconoscope type.

Telefunken Co. Convention date (Germany) 12th March, 1935.

472 073.—Image-intensifier for television, used in combination with a midget C.R. tube fed with low operating-voltages.

E. Michaelis. Convention date (Germany) 15th June, 1935.

472 162.—Electron-discharge device for converting light rays into equivalent electric currents by "abnormal" secondary emission. For use in television.

H. G. Lubszynski. Application date 15th January, 1936.

472 240.—Cathode-ray television receiver in which the picture is reproduced by incandescence upon a very thin sheet of light-refractory metal, instead of upon a fluorescent screen.

N. V. Philips Lamp Co. Convention date (Holland) 14th June, 1935.

472 274.—Means for running-up the driving motor to synchronous speed in a television transmitter of the intermediate-film type.

Baird Television and G. Dovaston. Application date 20th March, 1936.

472 293.—Saw-toothed oscillation-generator for the time-base unit of a cathode-ray television receiver.

Compagnie D'Usines à le Gaz. Convention date (France) 21st August, 1935.

472 401.—Eliminating disturbances created during the "flyback" stroke in television scanning.

Baird Television and P. W. Willans. Application date 20th March, 1936.

TRANSMITTING CIRCUITS AND APPARATUS

(See also under Television).

469 600.—Crystal-controlled short-wave oscillator with a resonant transmission-line coupling between grid and cathode.

British Thomson-Houston Co. Convention date (U.S.A.) 16th April, 1936.

469 860.—Modulating system in which the carrier-wave is automatically adjusted in accordance with the prevailing level of signal energy.

Wired Radio Inc. Convention date (U.S.A.) 24th December, 1935.

469 961.—Transmitter in which a "transmission-line" element is used to stabilise frequency.

Marconi's W.T. Co. (assignees of F. H. Kroger). Convention date (U.S.A.) 5th February, 1935.

470 286.—Method of coupling subsidiary feeders to a main transmission line for distributing modulated carrier-wave signals to a circle of subscribers.

R. E. H. Carpenter and P. P. Eckersley. Application date 25th March, 1936.

470 421.—Series-modulated transmitter in which

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the power radiated varies with the percentage of modulation.

Marconi's W.T. Co.; N. H. Clough; and E. Green. Application date 14th February, 1936.

470 543.—Phase-shifting circuit suitable for controlling the currents in a feed line, or for phase-modulation in a wireless transmitter.

Marconi's W.T. Co. (assignees of W. van B. Roberts). Convention date (U.S.A.) 9th November, 1935.

470 547.—Double-modulation method of signalling with ultra-short or decimetre waves.

C. Lorenz Akt. Convention date (Germany) 13th December, 1935.

470 572.—Multi-grid valve generator and modulator in which the plate is coupled to a frequency-stabilising circuit, and in which one grid is used as an accelerator and another grid as a suppressor.

Bronzavia Soc. Anon. Convention date (Belgium) 28th February, 1935.

471 128.—Method of preventing grid-current distortion in the final modulator stage of a wireless transmitter.

Marconi's W.T. Co.; E. Green; and N. H. Clough. Application date 27th February, 1936.

471 250.—Generating sustained oscillations by deflecting the electron stream in a cathode-ray tube.

Farnsworth Television Inc. Convention date (U.S.A.) 13th March, 1935.

471 423.—Method of increasing the efficiency of high-powered amplifiers as used for broadcast transmission.

Standard Telephones and Cables. Application date 3rd March, 1936.

471 549.—Transmission line for very high-frequency waves in which amplifier-valves are spaced at odd multiples of a quarter wavelength along the line and are matched with its impedance.

Kolster-Brandes, Ltd., and H. K. Robin. Application date 6th March, 1936.

CONSTRUCTION OF THERMIONIC DEVICES

469 283.—Electron-multiplier designed to allow an increased number of "targets" or cathodes to be used in a tube of given length.

General Electric Co. and W. H. Aldous. Application date 31st July, 1936.

469 404.—Electron multiplier in which the "impact" electrodes consist of wire grids or meshes arranged so as to avoid forming interference patterns.

W. E. Williams. Application date 23rd January, 1936.

469 477.—Amplifier tube of the secondary emission type in which the primary electron stream is caused to impact against a series of target electrodes.

Marconi's W.T. Co. Convention date (U.S.A.) 30th January, 1935.

469 488.—Electron discharge tube fitted with a succession of target electrodes, the later stages of which are back-coupled to an earlier stage.

Marconi's W.T. Co. Convention dates (U.S.A.) 28th February and 30th March, 1935.

469 900.—Electron multiplier in which a primary stream of electrons is caused to strike against a succession of "target" electrodes, and to produce secondary emission at each impact.

Marconi's W.T. Co. and G. F. Brett. Application date 3rd February, 1936.

470 026.—Electron multiplier in which the various "target" electrodes act as a series of electron guns, each projecting the amplified stream on to the next electrode.

Marconi's W.T. Co. and G. F. Brett. Application date 8th February, 1936.

470 102.—Electron multipliers in which a series of close-mesh grids are interposed between the cathode and output electrodes in order to cut down the intensity and velocity of the electron stream and so prevent over-heating.

Marconi's W.T. Co. and L. M. Myers. Application date 8th February, 1936.

470 480.—Cathode-ray tube in which the fluorescent screen is mounted on end-rollers which can be rotated to expose fresh portions of the screen when required.

Baird Television and J. L. Baird. Application date 13th February, 1936.

470 610.—Split-anode magnetron mounted inside a ceramic tube with end-discs secured by glass seals.

C. Lorenz. Convention date (Germany) 24th January, 1936.

470 618.—Method of mounting and supporting valve electrodes of circular or oval section.

C. Lorenz. Convention date (Germany) 21st February, 1936.

471 191.—"Storage" electrode for cathode-ray tubes in which the mosaic cells are formed by an oxide coating on an aluminium plate.

Baird Television; T. M. C. Lance; V. Jones; and P. W. Willans. Application date 29th February, 1936.

471 672.—Amplifier tube of the secondary-emission type in which a stream of electrons are deflected from side to side between two parallel plates whilst travelling towards an output electrode.

Marconi's W.T. Co. and G. B. Banks. Application date 8th February, 1936.

471 800.—Amplifier of the secondary emission type in which the electron stream passes through a series of pervious target electrodes.

G. Weiss. Convention dates (Germany) 8th January, 1st February, and 24th May, 1935.

472 284.—Arrangement of the deflecting plates and their supports in a cathode-ray tube.

F. H. Nicoll. Application date 20th March, 1936.

472 485.—Arrangement of the "target" electrodes in an electron multiplier utilising secondary emission.

Baird Television and T. M. C. Lance. Application date 23rd March, 1936.

473 398.—Preparing carbon-metallic surfaces of high secondary emission particularly for use in "electron-multipliers."

N. V. Philips' Lamp Co. Convention date (Germany) 10th February, 1936.

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